THE PICTURE OF THE TAOIST GENII PRINTED ON THE COVER OF this book is part of a painted temple scroll, recent but traditional, given to Mr Brian Harland in Ssu-Chhuan province (1946). Concerning these four divinities, of respectable rank in the Taoist bureaucracy, the following particulars have been handed down. The title of the first of the four signifies 'Heavenly Prince', that of the other three 'Mysterious Commander'.

At the top, on the left, is Liu *Thien Chün*, Comptroller-General of Crops and Weather. Before his deification (so it was said) he was a rain-making magician and weather forecaster named Liu Chün, born in the Chin dynasty about +340. Among his attributes may be seen the sun and moon, and a measuring-rod or carpenter's square. The two great luminaries imply the making of the calendar, so important for a primarily agricultural society, the efforts, ever renewed, to reconcile celestial periodicities. The carpenter's square is no ordinary tool, but the gnomon for measuring the lengths of the sun's solstitial shadows. The Comptroller-General also carries a bell because in ancient and medieval times there was thought to be a close connection between calendrical calculations and the arithmetical acoustics of bells and pitch-pipes.

At the top, on the right, is Wên *Yüan Shuai*, Intendant of the Spiritual Officials of the Sacred Mountain, Thai Shan. He was taken to be an incarnation of one of the Hour-Presidents (*Chia Shên*), i.e. tutelary deities of the twelve cyclical characters (see Vol. 4, pt 2, p. 440). During his earthly pilgrimage his name was Huan Tzu-Yü and he was a scholar and astronomer in the Later Han (b. +142). He is seen holding an armillary ring.

Below, on the left, is Kou *Yüan Shuai*, Assistant Secretary of State in the Ministry of Thunder. He is therefore a later emanation of a very ancient god, Lei Kung. Before he became deified he was Hsin Hsing, a poor woodcutter, but no doubt an incarnation of the spirit of the constellation Kou-Chhên (the Angular Arranger), part of the group of stars which we know as Ursa Minor. He is equipped with hammer and chisel.

Below, on the right, is Pi *Yüan Shuai*, Commander of the Lightning, with his flashing sword, a deity with distinct alchemical and cosmological interests. According to tradition, in his earthly life he was a countryman whose name was Thien Hua. Together with the colleague on his right, he controlled the Spirits of the Five Directions.

Such is the legendary folklore of common men canonised by popular acclamation. An interesting scroll, of no great artistic merit, destined to decorate a temple wall, to be looked upon by humble people, it symbolises something which this book has to say. Chinese art and literature have been so profuse, Chinese mythological imagery so fertile, that the West has often missed other aspects, perhaps more important, of Chinese civilisation. Here the graduated scale of Liu Chün, at first sight unexpected in this setting, reminds us of the ever-present theme of quantitative measurement in Chinese culture; there were rain-gauges already in the Sung (+12 century) and sliding calipers in the Han (+1st). The armillary ring of Huan Tzu-Yü bears witness that Naburiannu and Hipparchus, al-Naqqāš and Tycho, had worthy counterparts in China. The tools of Hsin Hsing symbolise that great empirical tradition which informed the work of Chinese artisans and technicians all through the ages.

中國科學技術史

李約瑟著

莫朝鼎

SCIENCE AND CIVILISATION IN CHINA

I have been astonished that so little has been published on the cultivation of the sugar-cane while the press has groaned under the folios of every other branch of the rural economy.

James Grainger (1723–1767),
Foreword to 'The sugar cane', a poem, 1764

SUGAR: the sweets (dates, honey, sugar) is [*sic*] much accounted of by the Arabians (living in hunger and nakedness) as very good for the health.

Charles Montagu Doughty (1843–1926),
Travels in Arabia Deserta, 1888

The sugar industry, as it exists today with all its ramifications is only a gradual evolution from the early and less complicated industry of a generation ago, just as the latter in turn was the out-growth of a previous more simple development. It is an advantage, as well as a satisfaction, at times to take note of our bearings and to trace back the details of our occupations to their early commencement. We obtain in this way a grasp of our subject such as is possible in no other way.

C. A. Browne,
'The unedited documents upon sugar in the archives of Seville'
Louisiana Planter & Sugar Manufacturer, vol. 55 (no. 7) p. 108, 1915

Rather perch in a wild wood
Rather drink from a mountain stream
Than consume fine rice and meat
And struggle for audience of the great

Wang Wei,
from 'Presented to the Duke of Shih-Hsing'.
Transl. G. W. Robinson, Penguin Books, 1973

If there is a Wutong tree in your home the phoenix will land on its branches

Chinese proverb

The hill and mountain lands, wherever accessible to the densely peopled plains, have long been cut over and as regularly has afforestation been encouraged and deliberately secured even through the transplanting of nursery stock grown expressly for that purpose. We had read so much regarding the reckless destruction of forests in China and Japan and had seen so few old forest trees except where these had been protected about temples, graves or houses, that when Rev. R. A. Haden, of the Elizabeth Blake hospital near Soochow, insisted that the Chinese were deliberate foresters and that they regularly grow trees for fuel, transplanting them when necessary to secure a close and early stand, after the area had been cleared, we were so much surprised that he generously volunteered to accompany us westward on a two days journey into the hill country where the practice could be seen.

F. H. King,
Farmers of Forty Centuries, 1911, pp. 151–2

Joseph Needham's
SCIENCE AND CIVILISATION IN CHINA

Joseph Needham directly supervised the publication of 17 books in the *Science and Civilisation in China* series, from the first volume, which appeared in 1954, through to the current work, which was in press at the time of his death in March 1995.

The planning and preparation of further volumes will continue. Responsibility for the commissioning and approval of work for publication in the series is now taken by the Publications Board of the Needham Research Institute in Cambridge, under the chairmanship of Dr Christopher Cullen, who acts as general editor of the series.

JOSEPH NEEDHAM

SCIENCE AND CIVILISATION IN CHINA

VOLUME 6

BIOLOGY AND BIOLOGICAL TECHNOLOGY

PART III

AGRO-INDUSTRIES AND FORESTRY

AGRO-INDUSTRIES: SUGARCANE TECHNOLOGY

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FORESTRY

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FORD FOUNDATION, PEKING

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CC	*Chou Chih* (as part of the title of a gazetteer)
CFP	*Chhün Fang Phu*
CFPT	*Chhüan Fang Pei Tsu*
CMYS	*Chhi Min Yao Shu*
CSS	*Chung Shu Shu*
FC	*Fu Chih* (as part of the title of a gazetteer)
HC	*Hsien Chih* (as part of the title of a gazetteer)
KCFP	*Kuang Chhün Fang Phu*
KTHY	*Kuang Tung Hsin Yü*
MS	*Min Shu*
NCCS	*Nung Chêng Chhüan Shu*
NFTMC	*Nan Fang Tshao Mu Chuang*
NSCY	*Nung Sang Chi Yao*
PTKM	*Pên Tshao Kang Mu*
THSCL	*Thai Hai Shih Chhai Lu*
TKKW	*Thien Kung Khai Wu*
TSP	*Thang Shuang Phu*
WCNS	*Wang Chên Nung Shu*

FOREWORD

Volume 6, part 3 was originally intended to incorporate fisheries, animal husbandry, agricultural industries and forestry. Sadly, however, resources and time have not allowed the completion of all of these sub-sections, and thus it is that the present volume contains the unlikely combination of sugarcane technology, written by Christian Daniels, and forestry, written by Nicholas Menzies. The present volume has been on the stocks since 1963, and it is a great pleasure to welcome these two collaborators in the enduring project. They know exactly what they are talking about, and the results will be of great use to readers of *Science and Civilisation in China.*

We are fortunate that Christian Daniels has incorporated in his contribution on sugar a very useful summary of five of the other most characteristic Chinese agro-industries: oil, paper, lacquer, indigo and of course tea. Perhaps we should note here that the paper industry, one of the clearest and most well-known examples of Chinese priority, and one of Francis Bacon's four most important world inventions, has already been dealt with in great detail in Tsien Tsuen-Hsuin's Volume 6, part 1. Oil, one of the first and most vital manufactured products of antiquity, we mentioned in Volume 6, part 2, and there also mentions of indigo and lacquer. Tea will be dealt with in Huang Hsing-Tsung's Volume on nutritional science.

Daniels' detailed analysis of the sugar industry allows a certain amount of generalisation on the other agro-industries also. What he characterises as the Chinese artisan's 'technological tool kit' is shared by many of the various traditional home-based industries in rural China: the edge-runner mill being used both in oil and sugar production and trip-hammers being common to the pounding of paper, tea and oil alike, to name but two already very familiar examples. Furthermore, he finds that all the different agro-industries have similar patterns in terms of world-wide technology transfer. He points to the trend of Chinese technological dominance and predominantly east-west transfer until the +17th century, followed by European dominance and west-east transfer after the +17th century, characterised by the return of old technology with the addition of innovations with the Jesuits and later industrialists. This pattern confirms the one we have established throughout many decades of research in this field.

Of note in Daniels' contribution is an attention to the important aspect of 'folklore'. This is a very important field where there is room for much further research. Also, Daniels has given many particulars of economic history which provide a useful backdrop to the study of the history of science. We are introduced in turn to the mysteries of 'bagasse', 'massecuite', 'sugar-candy' and so on.

In Nicholas Menzies' contribution on forestry, I was very struck by a curious little folk-tale which provides evidence for yet another first discovery for China, i.e. the ageing of a tree by the number of rings it contains. It appears that this fact was well known in the Sung dynasty while it took until Leonardo da Vinci for the principle to be recorded in the West.

When out in north-west Kansu, I often found myself wondering how the forests that were there formerly could have disappeared so easily. Reading Nicholas Menzies' contribution one understands that however good the Chinese were at managing forests and planting trees (and from his reports there were accomplished foresters in China from early times) they were also very good at cutting them down again, for a variety of purposes. One thing that I would like to point out is that the use of timber was not confined to the building of temples and palaces, but also formed the basis of machinery. All the early machines were made of wood, and without timber the parts required for, for example, the interconversion of rotary and longitudinal motion, could never have been put together.

In view of the recent worldwide concern over the cutting down of the rainforests, it is interesting to note that concern over the contradiction between exploitation and conservation of the forests goes back to the Chou. The Great Yü is supposed to have worried about this, and the *Tso Chuan*, *Mencius* and the *Chuang Tzu* all separately contribute to our knowledge of primitive Chinese ecology. It is also fascinating to note that the Chinese understood the water cycle and the relationship between deforestation and flooding in very early times. While it is true that respect for the balance of nature is wholly in keeping with ancient Chinese philosophy it is sad to see that in spite of this, deforestation still took place, with often disastrous consequences some of which have lasted even to the present day.

I should like to take this opportunity of including my thanks to the workers at the Institute, and especially to Angela King and to my research assistants, Jovanna Muir, Corinne Richeux and their successor Tracey Sinclair. I have greatly enjoyed working with them. I must also thank the new librarian we have, John Moffett, for his contributions. Others too deserve thanks, notably Diana Brodie and Katharine Lowe, my secretaries in the Institute and in the Master's Lodge at Caius College respectively. Now let us hear what Christian Daniels and Nicholas Menzies have to say.

Joseph Needham

The Needham Research Institute
Cambridge
December 1993

42a. AGRO-INDUSTRIES: SUGARCANE TECHNOLOGY

This contribution is dedicated to the memories of

NOEL DEERR

Sugar technican and pioneer historian of world sugar

and

JOHN DANIELS

Plant breeder of Fiji, historian of sugarcane and sugar,
and geneticist to the end

without whose works and help this part of the volume
would not have been possible.

AUTHOR'S NOTE

This contribution naturally follows on from the previous volume on agriculture, as is suggested by the title Agro-Industries. It was especially to treat the left-overs, so to speak, from Agriculture that Dr Joseph Needham, at the request of Dr Francesca Bray, invited me to join the project in December 1981. Volume 6, part 2, already bulging at over seven hundred pages, only had room for such down-to-earth subjects as ecological background, origins of agriculture, sources, field systems, tools and techniques, and crop plants. The great wealth and detail of Chinese source materials dictated that Dr Bray assign priority to the fundamental aspects of the subject. The wisdom of this decision is readily understandable when the reader is told that that volume was the first detailed general history of Chinese agriculture in a European language. Consideration of space, therefore, demanded that the emphasis, quite appropriately, be placed on staple crops of subsistence, and prevented full-length accounts of important commercial crops, such as sugar, tea and indigo, which played so significant a part in the rural economy of China. Likewise other agriculture-related topics originally designed to go into that volume, such as animal and vegetable oils and waxes, perfumes and essential oils, lacquer, tanning and the leather industry, apiculture, animal husbandry and pisciculture, also had to be left out.

At first glance the abandoned topics may appear as a hotchpotch, a chaotic mix if you like, but no one could possibly doubt their substantial content and great importance to the history of Chinese technology. As with agriculture *per se*, it would not be an exaggeration to say that their technologies greatly contributed to the material wealth of China, so envied by neighbouring Asians and distant Europeans since ancient times, and in that sense formed an integral part of the material basis that made possible the Chinese achievements in the various branches of science. The chief problem I faced was how to treat the medley systemically as a whole. After considerable deliberation I decided to concentrate on technologies with a plant (that is an agricultural or horticultural) aspect, that involved processing of some kind before consumption. Previous volumes in this series have dealt with specific parts of some of these processing technologies. One that comes immediately to mind is Volume 4, part 2 on mechanical engineering, in which much of the machinery examined was designed for processing agricultural produce. The development of Chinese technology clearly had close connections with agriculture and such related subjects as hydrology, and it is for the purpose of emphasising both the agricultural and the processing aspects of these technologies that I have chosen the term agro-industries. A detailed treatment of a select number of agro-industrial crops can

delineate the characteristics of agro-industries as a whole, and illustrate in a concrete fashion how technology mediated between nature, society and the economy.

In the summer of 1984 I spent three months at Cambridge collecting primary and secondary sources in European languages on a travel grant from the East Asian History of Science Trust. After returning to Tokyo I began exploring local gazetteers and translating relevant parts of agricultural treatises. Up until the first 'demarcation dispute' in August 1985 I had concentrated on five topics; oil and oil seed crops, tea, indigo, sugar and lacquer. With so many contributors involved, and with such a wide range of subjects covered in the Science and Civilisation in China Project, problems must inevitably arise as some topics naturally overlap with others. In the first round of the 'dispute' I lost tea to Dr Huang Hsing-Tsung[1] for inclusion in his treatment of nutritional science and fermentation technology, and in the second Dr Gert Naundorf appropriated indigo for his contribution on dyes. This forced me to reconsider my approach. If it was going to be difficult to give detailed accounts of five or six agro-industries why not treat a single one as representative of the whole? Moreover, at this point it had just emerged that like Dr Bray, I too faced a shortage of space: there was simply so much to tell about the five topics. The various reasons for eventually choosing to concentrate on cane sugar production are laid out in the text, and there is no point in repeating them here. But I would like to emphasise two points. First, this topic diplays *par excellence* how the seemingly divergent aspects of botany, agronomy, chemistry, mechanical engineering, technology transfer and economics are integrated in the technology of a single crop plant. Second, the importance of cane sugar production in India, West Asia, the Mediterranean and tropical America prior to the 20th century allows comparisons between different cultural spheres on a truly global scale.

This contribution begins with an outline of the concept of agro-industries, showing their relationship to one another, and their usefulness as an analytical concept for studying technological change, and ends with an overview of their oecumenical status in the light of the case study of cane sugar. To set the story of cane sugar technology in its proper social and economic context, an account of the way the Chinese consumed sugarcane and sugar, together with an outline history of sugarcane production precedes the main body of the work, which is a technological history divided under the following general headings. First comes sugarcane clones, species and origins, followed by sugarcane agriculture, and the various component chemical and mechanical engineering technologies of cane sugar manufacture. Next I trace the transfer of Chinese sugarmaking technology to East and South-East Asia, and it is here that we see the various mosaic patterns in the blending of Chinese technology with the societies and economies of different cultures. I believe that with the new surge in intra-Asian trade after the +16th century, not just sugar making, but a whole range of agro-industrial and other Chinese technologies, such as silk weaving, ceramics,

[1] 黃興宗

shipbuilding and so forth, were transferred, as technological systems, to countries in East and South-East Asia, where they reigned supreme until the 19th century at least. The job of filling out the blank spaces in this Chinese technological sphere of influence remains to be done, but we can be certain that it will throw a different light upon the historical role of Chinese technology before the coming of modern technological systems in the second half of the 19th century.

Most of the sources for cane sugar in China derive from the great Chinese agricultural treatises and local gazetteers, which have already been introduced in Volume 6, part 2. In view of the extensive use which I have made of gazetteers, a short exposition has been provided on their effectiveness as sources for agro-industries. Also, in order to help readers applying for photocopies through inter-library services, the holding locations of local gazetteers cited in this work have been appended to the bibliographical entries. A brief note on the method of citation appears in the explanatory piece preceding Bibliography A, into which all of the local gazetteers have been assembled, irrespective of date of publication (or in most cases date of preface).

The actual writing of the manuscript took place between 1986 and 1989 before I began my field surveys of traditional agro-industries in China. This meant that some new data, particularly those concerning chevron gears used by the Tai people[1] of Sip Song Panna (Hsi-Shuang Pan-Na)[2] in Yunnan on water-driven horizontal and animal-driven vertical double-roller sugar mills, could not be included, but interested readers may like to consult Daniels (7) in Japanese.

Many people have aided in the preparation of this volume. My thanks are due first and foremost to the East Asian History of Science Trust, which financed some of the research; I am also indebted to Mr George Hicks of Hong Kong, a generous donor to the Science and Civilisation in China Project, who kindly provided funds for a brief trip to Cambridge in 1982. My work was greatly encouraged by my supervisors at the University of Tokyo, Professors Tanaka Masatoshi[3] and Hamashita Takeshi,[4] and Ikuta Shigeru[5] of the Centre for East Asian Cultural Studies at the Tōyō Bunko, where I worked part-time for six years. Mention should be made of Professor Sakurai Yumio[6] of the University of Tokyo for his help with Vietnamese romanisation. After taking up a lectureship in Chinese History at Shūjitsu Women's University[7] in Okayama in 1987, Professor Sueyoshi Takakuni,[8] Head of the History Department, graciously allowed me to spend my holidays in Sydney, where I had immediate recourse to my father's vast store of knowledge of sugar and sugarcane and ready access to his personal library on the subject while writing. In Sydney I also benefited from conversations with Jack Cribb, a mechanical engineer formerly with CSR Limited, and for constant advice from Dr Charles Davis, sometime general manager technology of CSR Limited.

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ADDENDUM FOR AUTHOR'S NOTE

In November 1992 the University of Tokyo conferred the degree of Doctor of Letters (*Bungaku Hakase*[4]) on me for this study, and I would like to thank my supervisor Professor Hamashita Takeshi and all of the examiners, especially Professors Ogata Osamu[5], Kano Keiryō[6] and Kishimoto Mio for valuable comments and suggestions.

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(*a*) INTRODUCTION: GENERAL CHARACTERISTICS OF AGRO-INDUSTRIES IN CHINA

Chinese agricultural technology ranked as the most advanced in the pre-modern world.[a] Agriculture was the *pên*[1], root or primary sector of the Chinese economy, which provided the Empire with food, while manufacturing, trade and all other non-agricultural occupations constituted the *mo*[2] or secondary sector. Until the early 20th century Confucian intellectuals consistently viewed agriculture as the fountain-head of social stability and general prosperity in the Empire, and discouraged those parts of the secondary sector which they felt interfered with the original goals of agrarian sustenance. Yet some aspects of the disdained sector, for example products of household industry, such as raw-silk thread, raw-silk fabric, and cloth woven from vegetable fibres, were actively promoted. They contributed to the maintenance of rural self-sufficiency and became important as items of tax.

From ancient times China attained fame amongst its neighbouring countries in Asia, and even as far west as Rome, for the exquisite quality of its handicraft ware such as silk and lacquer.[b] From the Sung period production in the secondary sector expanded with population and urban growth and the consequent development of trade. This trend continued through the Ming and Chhing periods, and the range of speciality products increased to encompass some of those for which China achieved just fame in pre-modern times, such as tea, porcelain, paper, indigo, sugar, along with plant and vegetable oils. Most of these activities combined agriculture with handicraft production, and here we describe such production under the rubric, agro-industries.

(1) Six Representative Agro-industrial Crops

Agro-industries involve the processing of select crops, tree saps and other natural products to render them more useful to man. This endows them with extra economic value not possessed in their unprocessed state. W. H. Moreland examining agro-industries in India at the time of the death of Akbar in +1605 made two pertinent points:[c]

> First, [the category of agro-industries] comprises the different industries by which agricultural produce is worked up for consumption; in the aggregate they are of great

[a] As demonstrated in Vol. 6, pt 2.

[b] See Vol. 4, pt 3, p. 158 for a discussion of the favourable balance of trade for China against the West, generated from export silk and lacquer.

[c] See Moreland (1), pp. 155–6; Moreland called agro-industries 'agricultural manufactures'.

[1] 本 [2] 末

Table 1. *Uses for agro-industrial products*

	PRODUCTION BY EXTRACTION
Oil	Oils were one of the first manufactured products of antiquity being a major requirement of civilised life. Cooking, lights & candles (for household and votive use), lubrication for machinery & carts, mixing with lime to cauk boats were some of major uses.
Paper	Paper, invented about +200, was not developed specifically for writing as is widely supposed. In traditional Chinese society paper was used for operations such as wrapping, paper currency, burnt offerings, fans, lanterns, umbrellas, napkins and toilet purposes as well as writing.
Sugar	Sugar, available from about +200, as well as used as a food, and for food preparation, was widely used in China in medicine, ceremony, magic and religion, decorative materials, and as a feedstock for other industries such as wine making.
	PRODUCTION BY MODIFICATION
Indigo	In China, indigo was employed as a dye and medicine at least from the early Han dynasty.
Lacquer	Lacquer, a substance of great antiquity, was used for a variety of purposes including application to food utensils and ceremonial vessels of black with red interiors. It has been applied to *objets d'art*, musical instruments and furniture, with more complex techniques such as gold colour, silver and gold inlays up to the present times.
Tea	Tea has been used as a medicine and beverage since before the Thang dynasty.

industrial importance, seeing that they transform a large part of the raw material yielded by the land, whether grain, oil-seeds or sugar, fibres, drugs or dye-stuffs, and it is unfortunate for our present purpose that in Akbar's time, as in the present day, they commonly received less than their due share of attention.

His second point was, 'it is still to my mind indisputable that in the matter of industry India was more advanced relatively to Western Europe than she is today'. In the following pages we will furnish evidence of the advanced nature of Chinese activity in these fields. We will commence by examining six representative agro-industrial crops, the broad uses of which have been set out in Table 1; their development was driven by need rather than technology for the sake of technology. Tea, oil crops and sugar are all prepared directly from cultivated plants for alimentary consumption, others, such as indigo, paper and lacquer, support activities normally associated with more highly developed material cultures. Despite a diversity of origins and uses they all share the common feature of transforming plant material into a useful commodity by extractive and physio-chemical processes. There was a common pool of technological know-how, a technological tool kit so to speak, which the Chinese could draw on when cultivating and processing agro-industrial crops. The political and cul-

tural unity of the Han Chinese allowed for the smooth transfer of this technological kit, which made them one of the best agro-industrial producers of the ancient and medieval world.

The majority of the six representative agro-industrial crops have been, or are being examined in varying detail elsewhere in *Science and Civilisation in China.* Here the objective is to provide a brief introduction to each crop bringing out the generic technologies, unit processes and areas of artisan expertise. First let us summarise the general features of these crops to establish a basis for characterising agro-industries as a whole, and establishing the various components of the technological tool kit. In the rest of the study we will then follow in detail sugarcane and sugar technology, which includes elements of most generic technologies involved. In addition, sugar production is of great interest for technological transfer within Asia and between East and West, for it provides one of the earliest examples of technology of an oecumenical status.

(i) *Oil and oil seed crops*[a]

Oil crops have seeds which have distinct, membrane-bound, subcellular organelles called lipid bodies from which the oil is expressed by pressing.[b] Oils were one of the first manufactured products of antiquity, being a basic requirement of civilised life. Their uses included: cooking,[c] medicine,[d] lighting with oil and candles for household and votive use,[e] lubrication for machinery and carts, varnish, paint, pigments and mixing with lime to caulk boats.[f]

Oil production is distinctive in that various grades were extracted by altering the plant feedstock rather than modifying the essential substance with technology. The Diderot of China, Sung Ying-Hsing[1] (+1587 to after +1666), was quite specific about the appropriate feedstocks and their ranking for cooking and lighting in his *Thien Kung Khai Wu* (The Exploitation of the Works of Nature) of +1637:[g]

For use in eating, the oils of sesame seeds (*hu-ma*[2], also called *chih-ma*[3]),[h] turnip seeds (*lai-fu tzu*[4]),[i] yellow soy beans (*huang-tou*[5])[j] and cabbage (*sung-tshai tzu*[6] also called *pai-*

[a] Oil crops have been examined previously in Vol. 6, pt 2, pp. 518–26.
[b] Wolf (1), p. 418.
[c] Smith put his view forthrightly: oil was 'an article of daily diet to counteract the binding qualities of rice and other cereal foods'. See Smith, F. Porter (2), p. 61.
[d] *Ibid.* Smith recorded oil used extensively in 'quack and orthodox plasters', as well as for a range of general complaints.
[e] See Vol. 4, pt 1, pp. 78–91 for the story of oil, candles and lighting.
[f] *TKKW*, p. 306; see Smith, F. Porter (2) for a range of uses.
[g] *TKKW*, pp. 307–9. All translations in the text and footnotes are my own, unless otherwise indicated.
[h] *Sesamum orientale* L.
[i] *Raphanus sativus* L.
[j] *Glycine max* Merr.

[1] 宋應星 [2] 胡麻 [3] 脂麻 [4] 萊菔子 [5] 黃豆
[6] 松菜子

tshai[1] or white cabbage)[a] seeds are the best . . . the last in quality is hemp-seed oil (*ta-ma jen*[2])[b] . . .

The best lamp oil is that made from the kernels of vegetable tallow-tree seeds (*chiu jen nei shui yu*[3])[c] followed by rape-seed (*yün-thai*[4])[d] linseed oil (*ya-ma tzu*[5])[e] (grown in Shen-Hsi province, this plant is colloquially called *pi-shih chih-ma*[6] or wall-louse sesame; the oil has a bad odour and is inedible), cotton-seed oil (*mien-hua tzu*[7])[f] and sesame oil (the latter burns too quickly in the lamp), while chinese-wood oil (*thung-yu*[8])[g] and 'mixed' vegetable tallow-seed oil (*chiu-hun yu*[9]) are the worst . . .

For making candles, the best material is the vegetable-tallow bark fat (*chiu-phi yu*[10]);[h] next, castor oil (*pi-ma tzu*[11]);[i] next 'mixed' vegetable tallow-seed oil (*chiu hun yu*[9]) every *chin*[12] [600 grams] of which is solidified by the addition of white wax (*pai-la*[13])[j] next, the various clear oils solidified with the admixture of white wax; next, camphor-seed oil (*chang shu tzu yu*[14])[k] (it gives no less light than others, but some people dislike its scent); next, holly-seed oil (*tung-chhing tzu*[15])[l] (used exclusively in Shao-Chou[16]; the latter is rated low on this list because the oil yield of the holly seeds is small); the lowest in quality is beef fat (*niu-yu*[17]), which is widely used in north China.

As said earlier, extractive technologies are concerned with the most efficient ways of removing the oil held in the lipid organelles of the seed. Sung Ying-Hsing recorded four methods:[m]

1 *Pounding in a mortar* This method which was the most primitive and, in Sung Ying-Hsing's time, the major method in Korea, undoubtedly dated from prehistoric times.
2 *Boiling ground oil meal in water* The oil froth that rises is skimmed off into another pot. This method was used principally with castor oil.
3 *Twisting ground oil seeds in a sack* In northern China, sesame seeds were ground, placed in a course hemp sack and oil expressed by twisting the sack in opposite directions from each end.[n]

[a] *Brassica campestris* Ssp. *pekinensis*. As noted in Vol. 6, pt 2, p. 521, *Brassica* taxonomy is difficult, we have followed McNaughton (1), fig. 16.1. For other scientific designations in this section, we have followed Tanaka, Tyōzaburō (1), who treated the *Brassicas* mostly under their original Linnean binomials.

[b] *Cannabis sativa* L.

[c] *Sapium sebiferum* Roxb.

[d] *Brassica campestris* Ssp. *oleifera*.

[e] *Linum usitatissium* L.

[f] *Gossypium* sp. see Vol. 6, pt 2, pp. 536–9.

[g] *Thung* oil, *Paulownia tomentosa* Baill.

[h] Derived solely from the white tallow layer on the outside surface of the tallow or *Stillingia sebifera* R332 tree seeds.

[i] *Ricinus communis* L.

[j] Wax from a small winged insect *Ericerix pela* R11 (Vol. 4, pt 1, p. 80), for additional information see Sun & Sun (1), p. 221 where it is named as a *Coccus* sp.

[k] *Cinnamomum camphora* Sieb.

[l] Most probably *Ilex rotunda* Thunb.

[m] *TKKW*, pp. 311–19.

[n] Amami islanders employed this technology to express sugarcane juice; they twisted cane flattened stalks from each end. This method is illustrated in the *Nihon Sankai Meibutsu Zue, kan* 3, pp. 17b–18a of +1754, see Fig. 68. The sugarcane procedure may have evolved from oil processing technology.

[1] 白菜 [2] 大麻仁 [3] 橙仁內水油 [4] 芸薹 [5] 亞麻子
[6] 蝨虱脂麻 [7] 棉花子 [8] 桐油 [9] 橙混油 [10] 橙皮油
[11] 蓖麻子 [12] 斤 [13] 白蠟 [14] 樟樹子油 [15] 冬青子
[16] 韶州 [17] 牛油

4 *Edge-running and static pressing* The method consisted of disintegrating the seeds by roasting to crack the seed coat (with field crops such as sesame and rape) or alternatively by steaming (with tree crops such as tallow-oil tree and tung (*thung*)), then crushing the treated seeds with a hand-operated longitudinal travel edge-runner or animal-driven edge-runner running in a circular race to obtain a fine meal.[a] This meal was steamed in a double boiler and the oil expressed in a wedge press. Repeated steaming and pressing continued for a further one or two times. Sung Ying-Hsing claimed the secret of good extraction lay in the rapid transfer of the hot, steamed material into the wedge press.

In the late 19th century Alexander Hosie,[b] who personally investigated the edge-runner and static pressure regime, observed large edge-runners yielding an initial expression of oil prior to wedge pressing. Sung Ying-Hsing probably inadvertently omitted this fact in the *Thien Kung Khai Wu*. Hosie also showed that steaming, as well as supplying heat to aid in expression, added about 10 per cent moisture by weight, to help flush out the oil (see Fig. 1). The wedges were usually hammered in by hand, but some large installations had water-driven hammers in the 19th century.[c] The strategy of double pressing with steaming was practised with sugarcane processing too.

There was a clear progression in technology from simple expression of oil by a mortar through the range of extractive machinery as it became available. The only machinery not adopted was the roller mill, although it became available from the late +16th century, and was documented for sugarcane in the *Thien Kung Khai Wu* of +1637.[d] This was most probably due to two factors. First, the tolerances necessary to crush small seeds would be difficult to achieve with wooden rollers. Second, primary crushing in a large edge-runner weighing one to two tonnes followed by secondary pressing gave good extraction with reasonable rates. This method may have arisen before the +6th century as the *Chhi Min Yao Shu* (Essential Techniques for the Peasantry) mentioned large oil pressing houses (*ya yu chia*[1]).[e] During the Thang dynasty, water-driven edge-runners came on record for producing large quantities of oil in Buddhist monasteries to burn votive lamps in shrines and to light buildings at night.[f] In addi-

[a] See Ellis (1), p. 279 for a description of the traditional method of handling tallow seed. Sung Ying-Hsing listed an additional method for pre-treating vegetable tallow seeds. They were hammered with a pedal-operated trip-hammer mill to remove the seed hulls, and then ground in a small grinding mill (*hsiao shih-mo*[2]) to remove the black seed coat, exposing the white kernels which were then steamed and pressed in the usual manner, see *TKKW*, pp. 317–19.

[b] Hosie (6), pp. 218–23.

[c] Smith, F. Porter (2), p. 61.

[d] *TKKW*, p. 167.

[e] *CMYS*, p. 133. It is also possible that the initial disruption of seed could have been made by a water-driven trip-hammer in these early mills.

[f] Twitchett (3), p. 533.

[1] 壓油家 [2] 小石磨



Fig. 1. An oven over which oil seeds are being simultaneously roasted (right) and steamed (left). Steaming formed an important element of the Chinese agro-industrial tool kit; from the 1959 Chung Hua reprint of the original +1637 edition of the *Thien Kung Khai Wu*, Ch. 12, p. 69b.

tion, the *Vinaya* designated oil as one of the five foods permitted to sick monks,[a] and the *Suttavibhanga* listed it as one of the five sumptuous foods.[b] The prominence of oil consumption in Buddhist culture, may have led Buddhists to initiate large-scale oil production in China. The commentary on individual items in the *Suttavibhanga* explained, *oil* means sesamum oil, oil of mustard, ...[c] Sesame oil was listed as number one. The uncertainty of the date and means

[a] Rhys Davids & Oldenburgh (1), p. 27
[b] Horner (1), vol. 2, p. 342.
[c] *Ibid.*

of introduction of sesame to China has been discussed in earlier Volumes,[a] and though there is no space to go into the problem here, I suggest an introduction by Buddhists as a feasible hypothesis. Edge-runner pressing of oil seeds survived in China[b] and Iran[c] well into the 20th century, despite competition from modern rolling presses.[d] It is interesting that the Iranian method resembled the Chinese one except for the absence of steaming, a unique Chinese practice of great antiquity.[e] The edge-runner combined with static pressing technology appeared in the Mediterranean before the +14th century for oil and sugar processing. We shall discuss possible transmissions below.

(ii) *Sugarcane and sugar making*

Sugarcane and sugar making will be treated below in great detail, and the technologies are summarised at this point for comparative purposes only.[f] Sugar or sucrose is present in water solution principally in the large parenchyma storage tissues of sugarcane stalks. By varying the technology applied juice could be extracted and processed into a great number of forms: syrup, hard and soft grain sugar, sugar candy, molasses. Sugar as well as being a food was widely used in China in medicine, magic, ceremonies, preservatives and confectionery.

Sugar-making technology utilised a number of complex physio-chemical processes to gradually eliminate impurities leaving crystal sugar as a residue. The six basic steps included:

1 *Extraction (removal of fibre)* The juice of sugarcane has been extracted by most of the equipment available to Chinese farmers over the centuries: mortar and pestle, pedal- and water-operated trip hammers, edge-runners, rolling mills and roller mills with secondary pressing in wedge and beam presses. To this we can also add extraction by diffusion for about 200 years from +1500 to +1700. Diffusion the best available method, disappeared with deforestation, since large amounts of fuel were necessary to boil off added water.

2 *Clarification (removal of impurities)* Colloids, gums and suspended matter were removed from the juice with heating and skimming. From the Ming, if not earlier, lime came to be employed as a reagent, which enabled the skimming of a greater amount of precipitated impurities. During the +17th century the Chinese greatly improved lime clarification by separating the clarification process from the next operation, boiling: clear juice was drawn off from heavy precipitates in specially constructed clarifying buckets.

[a] Vol. 6, pt 1, pp. 172–3; Vol. 6, pt 2, pp. 525–6.
[b] Hosie (6), pp. 218–23.
[c] Hassan & Hill (1), p. 225, Wulf (1), pp. 296–300.
[d] See Brown, Shannon (1) for a record of 19th-century confrontation between traditional and European roller-mill extraction of oil seeds.
[e] See Vol. 5, pt 4, pp. 26–32 for a discussion of the antiquity of steaming.
[f] See following sugar sections for documentation of concepts mentioned.

3 *Evaporation (removal of water)* It is necessary to eliminate water before crystallisation can commence. In the Thang dynasty the Chinese used an Indian method of boiling several pans from the one fire, for fuel economy where appropriate, and a three-pan boiling arrangement appeared from the +16th century.

4 *Crystallisation (removal of inorganic salts by crystallisation)* At the right supersaturation, sugar crystallises out leaving the dissolved impurities in the syrup (molasses). The accurate determination of this striking point is the key to sugar boiling. There are a few rules of thumb such as feel of the syrup, how long it takes for a syrup thread to break, appearance of a drop of syrup in cold water and the like. Since early times sugar masters throughout the world have engendered an air of mystique about the art, to command higher remuneration. This has persisted to the present, even with modern aids such as thermometers and conductivity meters, there is still considerable margin for art as well as science.[a]

5 *Draining (removal of molasses and impurities)* Sugar crystals were separated from molasses by draining in inverted cones. The procedure was improved by adding moist clay to the surface of the cone so that small quantities of water percolated through the sugar to remove residual molasses adhering to the outside of crystals.

6 *Drying* Residual moisture was removed from sugar by sun drying.

I have summarised the main-stream sugar technology, but there are many significant variations. The Chinese adopted an Indian method of beating supersaturated sugar solutions to make a fine-grained sugar. The beating of sugar solutions at the right concentration caused immediate crystallisation, and remaining water was evaporated off by the heat of crystallisation, yielding a dry crystal sugar. Some districts utilised cold weather to grow large candy crystals, as sugar solutions become supersaturated with cold. The Chinese employed the same type of physical chemistry to concentrate alcohol solutions by freezing out water.[b]

In reviewing sugar technology we see all the machinery and physio-chemical processes practised with the processing of other agro-industrial crops, and additional ones such as roller milling as well. Diffusion was utilised in sugarcane processing for a time as with indigo, but it would be difficult to demonstrate a connection. The addition of lime as a reagent marked a most significant improvement, and I believe it not a coincidence that it was also applied with paper and indigo; lime additives formed part of the Chinese technologists' 'tool kit'. Application of heat remained common to all technologies examined to date, and steaming was a unique Chinese practice. Edge-running for juice expression followed by steaming of the residue and further expression of juice.

[a] This arises because the residual impurities, especially ash, have a variable effect on instrumentation.
[b] Vol. 5, pt 4, pp. 151–8.

was described in the earliest Chinese treatise on sugar, the *Thang Shuang Phu*[1] (Monograph on Sugar Candy) of c. +1154 by the Sung scholar and poet Wang cho[2]. This generic technology appeared in Persia and the Mediterranean by the +12th century for oil and sugar processing.[a] Interestingly enough artisans in these areas also practised paper-making technology of Chinese ancestry at about the same time.

(iii) *Paper*[b]

Paper was made from selected fibrous plants by digesting, washing and extracting the fibre, which was then deposited from a water suspension on a screen. The water drained away leaving a mat of fibre that was removed from the screen and dried to form sheet paper. The remaining plant constituents were discarded as impurities. Paper originated in China during the Han dynasty, if not earlier, but was not employed exclusively for writing as widely supposed. In pre-modern Chinese society and in the centuries after the Han period people used paper for such diverse operations as wrapping, paper currency, burnt offerings, fans, lanterns, umbrellas, napkins and toilet purposes as well as writing.

The four groups of plants utilised for paper making are indicated below with the time of first usage of the major plants indicated:

1 Bast fibre plants: hemp (Former Han), jute, flax, ramie, rattan
2 Paper mulberry (Later Han) and mulberry
3 Grasses: bamboo (mid-Thang), reeds, straw (Sung)
4 Cotton fibre and rags.

Artisans considered hemp and cotton as the best feedstock, but high demand for textile production ruled them out, leaving paper mulberry and bamboo to emerge as the chief raw materials in China.

The first description of paper making with bamboo occurred in the *Thien Kung Khai Wu* and included the following processes:[c]

1 prolonged soaking in water for one hundred days
2 pounding and washing to recover long fibres. Wang Shih-Mao[3] in his *Min Pu Su*[4] preface dated +1586 described large-scale operations using water-driven trip-hammers mounted on boats in rapidly flowing rivers in Shun-Chhang[5] county, Fukien.[d]

[a] Steaming was restricted to China.
[b] Paper and paper making have been discussed in detail in Vol. 5, pt 1. This exposition relies heavily on that volume, which should be consulted for authorities unless noted otherwise.
[c] *TKKW*, pp. 320–32.
[d] *Min Pu Su*, p. 40; Vol. 4, pt 2, pp. 394, 410.

[1] 糖霜譜 [2] 王灼 [3] 王世懋 [4] 閩部疏 [5] 順昌

3 boiling fibre for eight days in a high-grade lime solution to separate fibres, then washing fibre in fresh water
4 soaking fibre in wood ashes heated to boiling, straining and reheating for ten days to form a pulp. In a later account this is referred to as a steaming operation.[a]
5 pounding pulp to a 'dough' with a mortar or water-powered pestle
6 suspending pulp in a solution with adhesive additives and filler; submerging and lifting out screens with fibres caught on the screen
7 draining water from the screen, and then inverting the screen producing a sheet of paper
8 pressing sheets by the hundreds to remove most of the water and then drying them individually. The use of rope clutch presses for this operation has been discussed in a previous volume.[b]

The great range in texture and properties of paper is achieved by adding adhesive solutions and other liquids[c] for sizing to the pulp.

The extractive technologies involved in paper making were prolonged water maceration, assisted by pounding. The addition of lime as a macerating agent was most significant. In the account in Volume 5, part 1,[d] we demonstrated that bamboo paper first emerged in the mid-Thang, but that it remained of an unsatisfactory, brittle character until the Sung. I suggest that the improvement at this time may have resulted from the application of lime as a macerating agent. The first textual reference to this practice appeared in the *Thien Kung Khai Wu* of +1637, though it certainly harks from an earlier age, as the Persian paper manufacturing technique of Chinese provenance described in Ibn Badis' *Kitab 'Umdat al Kuttab'* (Book of the Supports of the Scribes) of +1061 included the use of lime.[e] In addition, lime functioned as a reagent in paper, sugar and indigo manufacture; the first textual reference for indigo occurred in the +6th century *Chhi Min Yao Shu*.[1] The use of steam as an agent to effect extraction, in this case of unwanted materials, is another example of the agro-industrial 'tool kit' in operation.

In looking for associations between paper making and other Chinese handicraft industries, we must not forget felting. In Volume 5, part 1 the similarity between the two crafts was noted, but no evidence was found of any possible interaction.[f] This must be kept in mind as the two techniques are similar, and leather making may have been one of the sources of lime as a chemical additive,

[a] See Vol. 5, pt 1, pp. 72–3 for Yang Chung-Hsi's record of the twelve steps in paper making in 19th-century Chekiang.
[b] Vol. 4, pt 2, p. 209 and Fig. 464.
[c] Gypsum, gums, starch and the like.
[d] Vol. 5, pt 1, pp. 60–1.
[e] See translation in Hassan & Hill (1), p. 192.
[f] Vol. 5, pt 1, p. 36.

[1] 齊民要術

since Chinese in the 1920s and Islamic texts of much greater antiquity mentioned its role as a means of removing fur from the skin of animals.[a]

Paper-making technology diffused from China to Persia during the +8th century, and had arrived in Europe by the +12th century.[b] In both cases this merely indicated the establishment of paper mills, but we suspect that the knowledge of paper had actually arrived some two centuries earlier. Paper entered Europe through Spain having travelled across north Africa during the +9th and +10th centuries.

(iv) *Indigo, a blue dye*[c]

Various crops contain a colourless glycoside indican, the precursor of the blue dye, indigo. Indican was extracted by diffusion in water and split into colourless indoxyl and glucose. The indoxyl was then oxidated to indigo by beating the solution in air, and the resulting indigo precipitated as fine flakes, a form in which it was collected and dried. Plants remained the principal source of indigo until Johann Friedrich Wilhelm Adolf von Baeyer (+1835 to +1917) succeeded in synthesising it in 1883. The advent of synthetic dyes spelt the demise of the agro-industrial production of indigo, in spite of 'natural' indigo being more effective because it carried traces of indigotin, indiubin, indigo brown, indigo gluten and indigo yellow which gave the dye better affinity for fibres, and increased fastness properties.[d]

In China, we find indigo as a dye and medicine at least from the early Han dynasty, and sources also mentioned it in association with advanced agronomical technique from antiquity. It was one of the first crops for which we have evidence of transplantation; rice was the other.[e] The demand for indigo as a dye increased to unprecedented levels from the Ming with the spread of cotton cultivation and cotton weaving, though the technique for extracting indigo boasts one of the longest recorded histories of all the agro-industries.[f] The basic technique appeared successively in the *Chhi Min Yao Shu* of c. +535,[g] the *Thien Kung Khai Wu* of +1637,[h] the *Fu Chün Nung Chhan Khao Lüeh*[l] of +1903,[i] and in Alexander Hosie's account of the late 19th century.[j]

Indigo can be extracted from a range of plants that have indican in their

[a] Hommel (1), pp. 209–10; Hassan & Hill (1), p. 197. Lime also had a tightening effect on the fibres of leather.

[b] Vol. 5, pt 1, p. 296

[c] Indigo will be discussed in detail in the part of Vol. 5 dealing with pigments, dyes and adhesives.

[d] See Farris (1), pp. 366–7 and Sachs (1) for chemistry of indigo.

[e] Vol. 6, pt 1, pp. 277 and 279.

[f] For a scientific study of Chinese indigo, see Satō Shinjirō (1).

[g] *CMYS*, p. 270

[h] *TKKW*, pp. 118–19.

[i] Ho Kang-Te (1), *Hsia*, pp. 7b–8b.

[j] Hosie (6), pp. 188–9.

[l] 撫郡農產考略

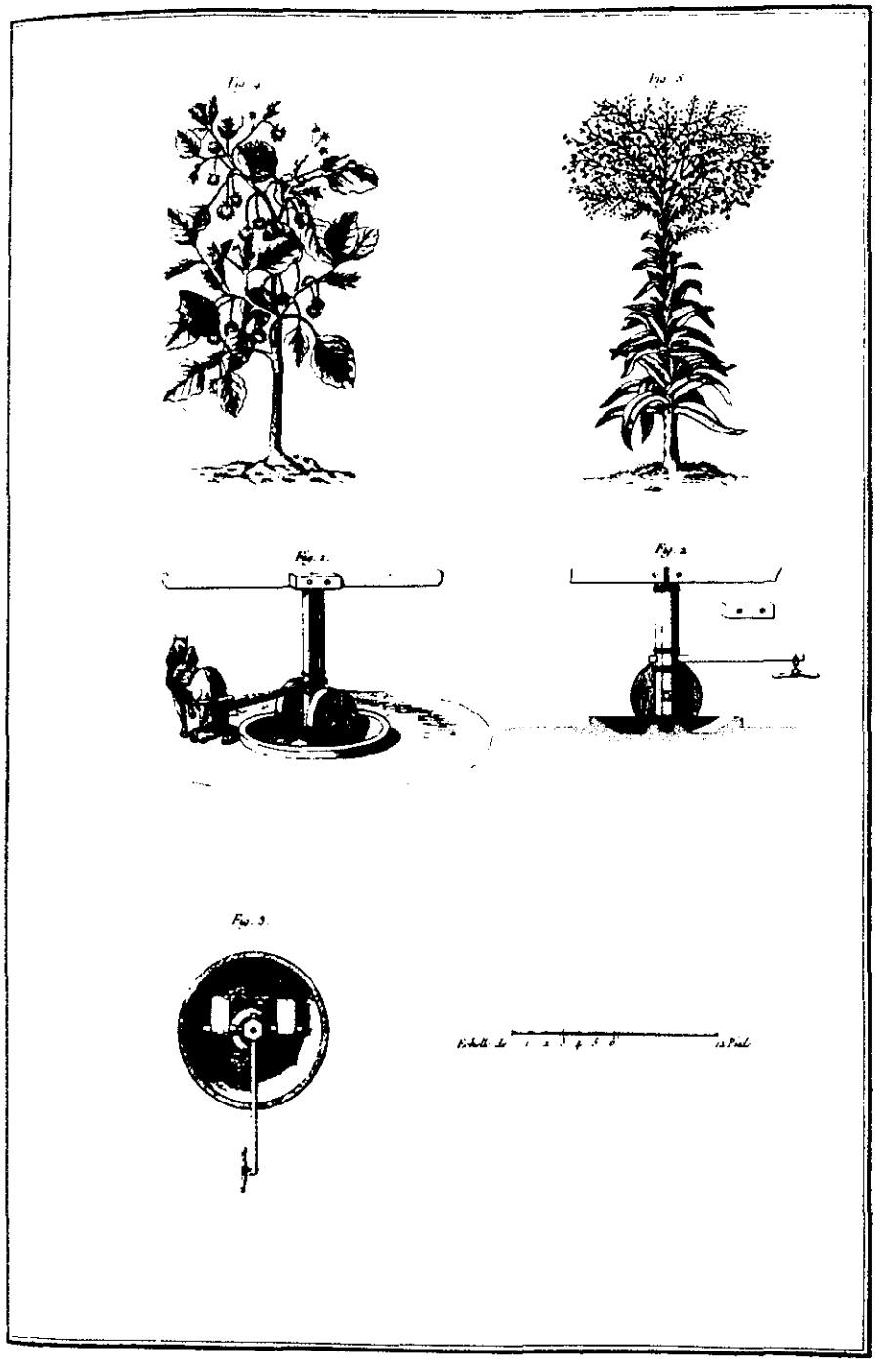


Fig. 2. The upper frame shows the indigo plant from the West Indies. The middle and lower frames illustrate a horse driven edge-runner used for crushing the indigo plants after diffusion, which was a peculiar French innovation. The small balanced edge-runner was a European invention, possibly designed by Leonardo da Vinci; from Beauvais-Raseau (1), pl. 11.

leaves.[a] It was manufactured all over the world, and the principal plants came from small leguminous shrubs of the genus *Indigofera* of which there are over 300 known species (see Fig. 2). *Polygonum tinctorium* was widely cultivated in south and central China both before and after the introduction of *Indigofera tinctoria* to China during the Thang dynasty.[b] Europeans obtained their indigo from woad, *Isatis tinctoria* L., a cruciferous, mustard-type herb, which later found its way to China where it was known by the names *sung-lan*[1] and *chha-lan*[2] and cultivated to a certain extent.[c] Woad remained the dominant source of indigo in Europe until the opening of the sea route to India in +1498. From this point in time indigo from India and later indigo from *Indigofera* sp. in the Caribbean caused the gradual demise of European woad. Proponents of woad waged a strong rear-guard action, and some governments even prohibited the 'devil dye' (indigo) for several years.[d]

From the +17th century indigo production assumed increasing importance in tropical and some temperate areas of the world. Dauril Alden has stated:[e]

> Until somewhat more sophisticated techniques were introduced in India during the nineteenth century, the dye was manufactured by approximately the same techniques the world over. The freshly cut leaves, harvested from two to seven times a year depending upon locale, were placed in vats and allowed to ferment in warm water for several hours until a yellowish orange pigment appeared. This slime was then drawn off to so-called beating vats, where it was agitated by bamboo sticks to induce oxidation, the resulting *indicum* gradually settling out as a blue precipitate which accumulated as sludge on the bottom of the vat. After the water had been drained off, the sludge was removed to another vat and immediately boiled to prevent further fermentation which might injure the dye's quality. Then it was filtered, dried, and cut into large cakes which were stored to await transportation to market.

We have quoted the generalised world-picture to highlight the significant differences in Chinese procedure. In China operators placed large amounts of leaves and stems in vats, but treated smaller amounts in jars and tubs.[f]
The main processes included:

1 *Diffusion/'fermentation'* The Chinese did not consider this critical and diffusion/'fermentation' could continue from one day to a week. This was probably a function of temperature, the time not being critical.[g]

[a] See *TKKW*, pp. 118–19.
[b] Vol. 6, pt 1, p. 158.
[c] *Ibid.*; *TKKW*, p. 118.
[d] Alden (1), p. 38.
[e] *Ibid.*, p. 36. Alden provided a world-wide survey of indigo production during the +17th and +18th centuries. For comparison with Brazilian methods, also see Smith, R. S. (1).
[f] *TKKW*, p. 119. The *Fu Chün Nung Chhan Khao Lüeh* of 1903 described these tubs as precipitation buckets with pegs near the bottom for draining off the liquid, see Ho Kang-Te (1), *hsia*, pp. 7b–8a. There may have been interaction with sugar boiling.
[g] Tajiri (1), p. 46, fn. 38. The main means given by European experts in 19th-century India for determining the length of the first process was loss of water in the vat, immediate bursting of bubbles, orange tint of water, sweet pungent odour, see Lock (1), p. 859. Without further research there is no reason to believe that any of these phenomena have anything to do with the completion of indican diffusion. Premature cessation of diffusion could leave large amounts in the discarded leaves.

[1] 菘藍 [2] 茶藍

2 *Beating process* After the liquid was drawn off to the beating vats the Chinese added a large amount of lime water to help precipitate the indigo and then commenced beating. The lime precipitated the desired extract indigo, which contrasts with sugarcane manufacture where it was the impurities that were precipitated; it is intriguing to see artisans utilising the same generic technology for different purposes. The Chinese strategy of adding large amounts of lime, contrary to the fears of European practitioners, ensured early and complete precipitation of indigo. Yet it was necessary to ensure that quality remained unaffected, and Hosie observed that operators prepared lime very carefully so that it became a pure solution of calcium hydroxide without any suspended particles.[a]

3 *Boiling* The Chinese did not boil to prevent further oxidation. Europeans practised boiling to stop what they termed fermentation. They misunderstood the process, for it was not one of fermentation, but a process of oxidation.[b] The 'boiling' may have had some stabilising effect on the dye.

Descriptions of technique in India and the New World, stressed the critical nature of the oxidation/precipitation step.[c] If the beating procedure was allowed to go on too long the precipitated indigo commenced dissolving and could not be recovered.[d] I suggest that the Chinese solved this problem by adding lime, thereby turning a critical point into a routine operation. Complaints by 19th-century Europeans about the large amounts of lime in indigo from Java[e] and the Philippines[f] indicated the practice of Chinese methods in these countries, albeit not applied very carefully.

I will conclude this section on indigo by noting the practice of a dry and semi-dry method of manufacture apart from the wet method discussed above. In Japan, oxidation was conducted dry, in the intact leaf, by raking large beds of leaves with occasional addition of water over a period of 100 days. The leaves were then finally pounded into cakes, packed and distributed as indigo dye. I

[a] Hosie (6), p. 189. Robert Fortune (+1812 to +1880) on his travels in south China observed Chinese operators adding 30 *chin* (18 kilos) of lime to every 400 *chin* (240 kilos) of liquid, see Tajiri (1), p. 46. fn. 38. The addition of small quantities of lime after the beating process had ended was not altogether unknown to the Indians, but they considered it as a reagent for use when things went wrong rather than a desirable routine procedure, Balfour (1), vol. 2, p. 336. See Balfour (1), vol. 2, pp. 332–8 for a comprehensive summary of indigo in 19th-century India.

[b] Some authors described this as a fermentation process, which is clearly incorrect since no fungi, yeast or bacterial enzymes are at any time added. It is a diffusion and oxidation process. Even the preparation of the *sukumo*[1] dye in Japan which entails the application of water over a hundred-day period is an oxidisation and not a fermentation process. Interestingly enough, this method gradually oxidises the indigo *in situ*, that is in the leaf itself (the art lies in keeping the reactions under control over a long period of time), while the other method relies on extracting the indican from the leaf before oxidation.

[c] Balfour (1), vol. 2, pp. 335–6, Smith, R. S. (1), p. 184.

[d] John Augustus Voelcker, examining the whole problem of oxidation/precipitation of indigo by beating suggested that the beating action might merely be a means of precipitating the indigo mechanically. See Voelcker (1), p. 197.

[e] Lock (1), p. 860.

[f] Mac Micking (1), p. 297.

[1] 蓼

have had the pleasure of observing the wonderful procedure on a number of occasions, and include a brief account below as an example of the artistic component in agro-industrial processes. Available sources confirm the use of a dry method in China during the late 19th and 20th centuries, but it remains uncertain whether the technique was the same as that of the Japanese. Though I lack documentary proof at present, I speculate that this process may have been the pristine archetypal method of indigo extraction, lying at the same technological level as brick tea and amorphous sun-dried sugar (*shih mi*[1]).

(v) *Lacquer*[a]

True lacquer, as opposed to the lac of India and the Islamic world and the varnish of later European imitators, was made from a latex extracted from a small group of plants in the family Anacardiaceae that possess the peculiar property of hardening on contact with moist air when applied in thin layers on wooden and metal objects. A hard, durable, heat-resistant surface that can be highly polished results. In addition, the surface was impermeable to water and resistant to acids and alkalis.[b] The process differed radically from varnishing and similar processes, which achieved their surface by applying a 'varnish' from which a solvent evaporates off leaving a deposit of resin. There was no evaporation process with lacquer for the hard surface was produced by the action of an oxidising enzyme laccase on phenolic compounds, catechols, the main constituents of the latex.[c]

Lacquering is one of the older agro-industrial arts in East Asia known from crude objects discovered in archaeological remains dating from as early as −5000. Yet it was the −6th century before lacquerware appeared as a mature art exemplified in objects found in tombs in Shan-Hsi.[d] During the Warring States period lacquer was applied to leather armour and weapons, musical instruments, utensils for food, ceremonial vessels and coffins. In addition, specialised lacquered objects appeared: *ming-chhi*[2] 'spirit utensils', small objects imitating aspects of daily life, for tomb interment;[e] *liên*[3], cases for holding toilet

[a] The only previous discussion of lacquer in any detail in this work concerned the striking story of a lacquer crab elixir. Crab tissues contain an inhibitor of the laccase enzyme that hardens lacquer, see Vol. 5, pt 4, pp. 207–10.

[b] *Ibid.*, p. 208, fn. i; Light Industry (1), unnumbered pages before plate 123: Thote (1), p. 266.

[c] The chemistry of lacquer formation was discussed in Vol. 5, pt 4, p. 209. I am indebted to an unpublished manuscript by John Winter (deposited in the East Asian History of Science Library, Cambridge) for an understanding of the recent Japanese research on practical aspects of the chemistry of lacquer formation. See Winter, J. (1). Winter also recommends the following for an understanding of Chinese and Japanese lacquer work, Sawaguchi (1), Arakawa (1), Shen (1), Garner (1), von Ragué (1).

[d] See Thote (1), p. 266 for a summary of archaeological finds of lacquer in China. He gives a map showing the provenance of lacquerware for the Neolithic to the unification by the *Chhin* in −221. For a study of the technology and organisation of lacquer production in ancient China see Satō Taketoshi (1), pp. 205–307 and Tu Shih-Jan *et al.* (1), pp. 202–5.

[e] Thote (1), p. 412.

[1] 石蜜 [2] 冥器 [3] 匳

Table 2. *Main lacquer-producing species*

Species	Locality used	Catechol type	Miscellania	References
Rhus verniciflua Stokes (Syn. *R. vernicifera* D.C.)	China, Korea, Japan	Urushiol (3-subst. C15)	Deciduous tree & most important species	Garner (1), Ohwi (1), Majima (1)
Rhus succedanea L.	S. China, Indo-china, Japan	Laccol (3-subst. C17)	*Haze* or 'wax tree' in Japan	Garner (1), Ohwi (1), Majima (1)
Rhus ambigua Lavall ex Dipp. (Syn. *R. orientalis* Schneid.)	Taiwan, Ryūkyū Is., Japan	Laccol (3-subst. C17)	Woody vine, yields *tsuta-urushi* (ivy lacquer)	Garner (1), Ohwi (1), Majima (1)
Rhus trichocarpa Miq.	Japan	?	Deciduous tree, *yama-urushi* (mountain lacquer)	Garner (1), Ohwi (1)
Melanorrhoea laccifera Pierre	Cambodia	Moreacol (structure uncertain)	Yields Cambodian lacquer	Garner (1), Majima (1), Bertrand & Brooks (1)
Melanorrhoea usitata Wall	Burma, Thailand	Thitsiol (3-subst. C17)	Yields 'thitsi' or Burmese lacquer	Garner (1), Majima (1)
Semecarpus vernicifera[a]	Taiwan	Laccol (3-subst. C17)	Yields Taiwanese lacquer	Majima (1)

Adapted from Winter, J. (1), n.p.

[a] Name used by Majima (1). Following Li Hui-lin (1) this taxon is presumably *Semecarpus gigantifolia* Vidal (Syn *S. vernicifera* Hayata & Kawakami).

objects;[a] figures sculpted in wood and lacquered representing divinities or monsters.[b] Lacquer has been applied to materials of increasing complexities such as gold colour, silver and gold inlays on *objets d'art*, musical instruments and furniture up to the present time.[c] Lacquer latex mixed with crab tissue served as an elixir and a minor alchemic reagent for Taoist practitioners,[d] and ground hard lacquer formed a minor constituent of gunpowder.[e] Artisans applied it to prevent leakage from containers; in the +12th century earthenware jars for storing sugarcane juice, called lacquered jars (*chhi-weng*[1]), were 'lacquered inside and out to stop the juice from leaking',[f] and during the +13th century lacquer paper (*chhi-chih*[2]) lined the bamboo containers for transporting fish fry long distances from Chiang-Chou[3], present day Chiu-Chiang[4] in Chiang-Hsi to Fukien and Chekiang.[g] It truly performed a myriad of functions, industrial as well as artistic.

The main plant sources for the latex in China, Japan and South-East Asia are given in Table 2. Among those listed, *Rhus verniciflua* Stokes yielded most of the lacquer in China, Korea and Japan, and this remains the position at the present time (see Fig. 3). However, the presence of appropriate taxa in South-East Asia and Japan indicated that the technology may have advanced on a wide geographical base. Kenjō Toshiko has shown that the rate of hardening varies depending on the species of lacquer tree, those from South-East Asia curing more slowly than *Rhus verniciflua* from China and Japan.[h] The latex is commonly tapped from *Rhus verniciflua* after the tree has attained an age of eight to nine years, by making incisions through the bark, and collecting the latex in bamboo receptacles from June until January of the following year (see Fig. 4). During the 1930s the Chinese divided the tree-tapping season into three periods, all of which bore latex of different quality. The *chhu piên tao*[5] period, which fell in June and July, yielded the poorest quality latex that easily deteriorated as it contained much moisture. The *chung piên tao*[6] period of August to November furnished the greatest quantity of latex and that of the best quality too, while the two months of December and January, known as *chung piên tao*[7], yielded the second best quality latex.[i] During the late 19th century and 20th century taskmen made incisions at different places on the tree and collected the exudations

[a] Thote (1), p. 411.
[b] *Ibid.*, p. 418.
[c] See Scott (1) and Light Industry (1), plates 123–41 for excellent colour photographs of contemporary Chinese lacquered objects.
[d] See Vol. 5, pt 4, p. 175.
[e] See Vol. 5, pt 7, pp. 42, 118, 122.
[f] *TSP*, p. 4a.
[g] *Kuei-Hsin Tsa-Chih, Pieh-Chi, shang*, 5a.
[h] See Kenjō (3), pp. 32–9.
[i] Kōain Kachū Renrakubu (*1*), pp. 35–6.

[1] 漆甕 [2] 漆紙 [3] 江州 [4] 九江 [5] 初邊刀
[6] 中邊刀 [7] 終邊刀

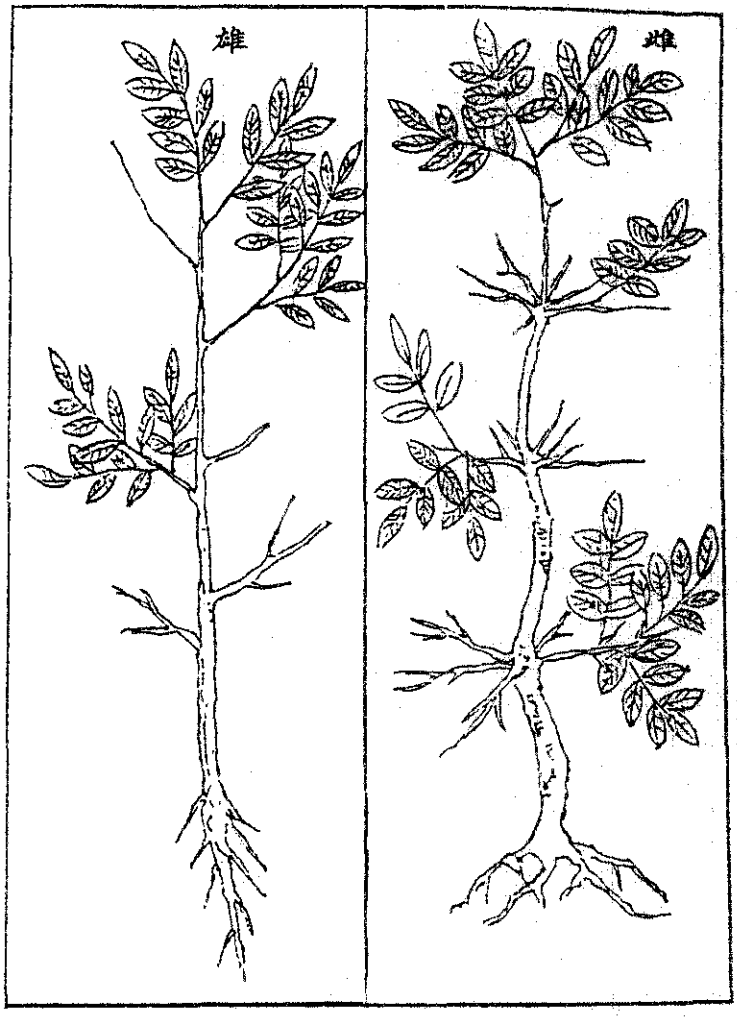


Fig. 3. Male (right) and female (left) plants of the lacquer tree, probably *Rhus vernicaflua* Stokes, as depicted by Yamaguchi Ichitarō in his *Shitsugyō Zensho* of 1892 (between pp. 8 and 9). The male tree apparently grew more quickly, and yielded greater quantities of latex than the female tree, but inability to bear seeds rendered it useless for wax making. Yamaguchi (pp. 8–9) claimed that differences in the roots and leaf shapes distinguished the male from the female; the roots of the female tree were rhizome-like emitting offshoots, and the leaves were round.

seven times over a period of roughly fifty days with an interval of about seven days between each operation. After tapping, a tree could be allowed between five to seven years to recover, but annual tapping of the same tree was by no means unknown.[a] In Japan, and sometimes in China, smaller branches of less than 3cm were cut off and soaked in water for ten days, and the sap collected

[a] Hasegawa (*1*), p. 4; Nōshōmushō Shōkōkyoku Kōmuka (*1*), p. 5; and Wilson, E. H. (*1*), vol. 2, p. 69. For tapping trees in 19th-century Japan see Yamaguchi Ichitarō (*1*), pp. 42–54. Taniuchi Chikitsu wrote that the Vietnamese tapped trees continuously for three to five years; see Taniuchi Chikitsu (*1*), pp. 35–60.



Fig. 4. Chinese method of tapping lacquer trees in the late 19th century. Workers standing on poles secured between two trees cut through the bark, and placed bamboo receptables below the incisions to collect the latex, from Nōshōmushō Shōkōkyoku Kōmuka (*1*), between pp. 4 and 5.

to prepare a poorer quality lacquer (*seshime*) used for the initial coatings of objects.[a] This procedure kills the tree, but it will regenerate from the roots with five or six shoots, which can be tapped after about six years. The lacquer tree also bore seeds which were pressed for manufacturing wax (see Fig. 5).

The latex is white or grayish in colour and of the consistency of molasses. The colour darkens to yellow-brown then to black on exposure to air. It was beaten in shallow tubs to homogenise fractions, and strained through hempen cloth to

[a] Rein (1), p. 344.

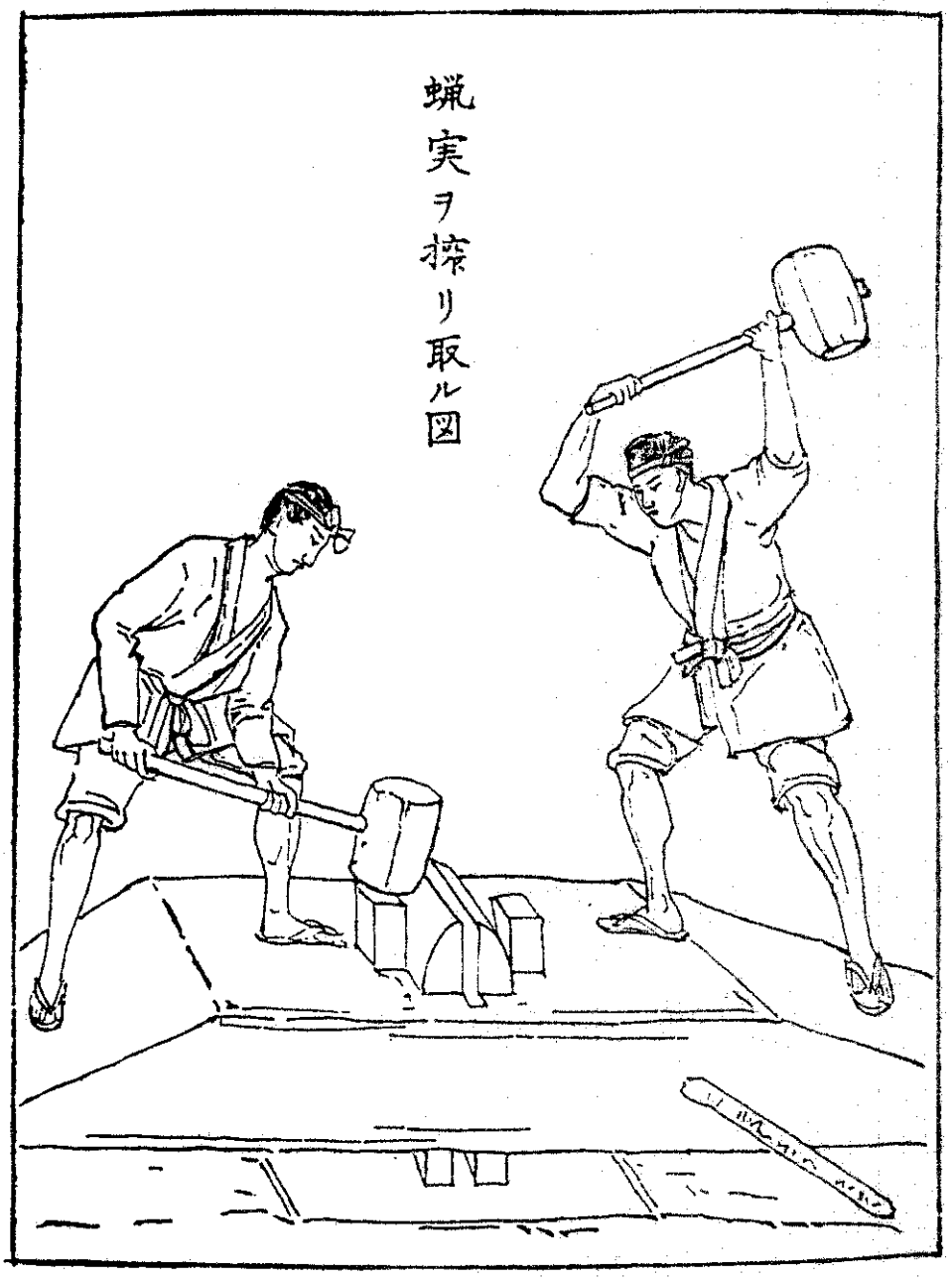


Fig. 5. A vertical wedge press, called a *daidō*[1], for pressing ground and steamed seeds of the lacquer tree, probably *Rhus verniciflua* Stokes, to make tallow in 19th-century north-east Japan; from Yamaguchi Ichitarō (*1*), between pp. 36 and 37. The operators placed bags containing ground seeds between the two vertical blocks which they compressed with wedges driven home by wooden hammers from either side. The *daidō*[1] was constructed with exceptionally hard timber, such as that of the *Keyaki*[2] tree (*Zelkova serrata*), and obviously functioned very efficiently for the two wedges applied pressure directly to both sides of the seeds. In most other presses the wedge exerted force driving the material against the side of the container (see Fig. 69).

[1] 大胴　　[2] 楔

Table 3. *Constituents of lacquer latex (percentages)*

	Catechols	Carbohydrates	Nitrogenous Compounds[a]	Water	References
Typical range for *R. vernicifiua*	65–70	4–8	2–4	18–29	Kumanotani (1), Kenjō (1), (2), (3)
Other lacquer latex					
Thai (*R. succedanea?*)	58.3	1.5	3.4	30.6	Kenjō (3)
Taiwanese (*S. vernicifera?*)	43.2	16.7	2.1	29.8	Kenjō (3)
Burmese (*M. usitata?*)	48.1	3.2	2.6	27.5	Kenjō (3)

Adapted from Winter, J. (1), n.p.

[a] Mostly of unknown composition; the laccase content is considered to be less than 1 per cent. The activity of laccase in *M. usitata* (Burmese lacquer tree) was found to be about 20 per cent of that in the Japanese lacquer tree, see Oda, Ishida & Honda (1).

remove physical impurities. The raw lacquer was then heated and stirred over a slow fire or in sunshine to attain a uniform consistency,[a] and to remove some moisture and create a scum so that impurities may be skimmed off. Next, it was stored in sealed airtight containers. The overall composition for lacquers of different origins is set out in Table 3. It can be seen that catechols in *Rhus verniciflua* amount to 65–70 per cent and water 18–29 per cent, with the enzyme laccase being less than 1 per cent. Raw lacquer is a water-in-oil emulsion, with the catechols in the oleaginous phase and the enzyme laccase in the aqueous phase along with carbohydrate and nitrogenous compounds. There are some differences in laccases; Oda, Ishida & Honda have demonstrated that the laccase from *Melanorrhoea usitata* Wall from Burma is only about 20 per cent as active as *Rhus verniciflua.*

In its essentials the lacquering process consisted of applying successive coats of lacquer to an object and polishing it to a fine surface between each coat.[b] As well as objects, lacquer has been applied in successive layers to cloth, shaped as an object; this method gave incredibly light ware.[c] Lacquer possesses the peculiar property of attaining maximum hardness in the presence of moisture. Experiments by Kenjō[d] have shown that it will not harden if the relative humidity remains below 43 per cent, but conversely, curing in too high a relative humidity results in hard films rough in texture; optimum humidity lies at about

[a] If left to stand the latex will form several layers with different profiles.

[b] See Smith & Strange (1) for a comprehensive survey of methods of application.

[c] In modern times the same result has been achieved by coating clay objects and then removing the clay after several applications of lacquer, see Light Industry (1), text before pl. 123.

[d] Kenjō (1).

55 per cent. Yet if applied in thick layers only a thin top coat will set, leaving the bottom layers liquid as they have no direct contact with the moisture in the air. Therefore applications could only be made in thin layers with ample time allowed for setting and polishing before painting the next coat. In order to build up a thickness of lacquer for incising designs, as for the *thi-hung*[1] or carved red lacquer of the Ming, artisans applied as many as two hundred layers; lacquer painting was very labour-intensive and time-consuming work.[a] The Chinese realised early, at least by the −3rd century, that optimum conditions for hardening were achieved by storing freshly lacquered objects in a special room called a shady room (*yin-shih*[2]).[b] The Japanese placed the object in a damp box or chamber after each application of lacquer.[c]

This peculiar requirement for hardening probably affected the laccase enzyme. Laccase is a glycoprotein, which Yoshida[d] has demonstrated by experiment to be necessary for hardening of lacquer. He also observed that as well as laccase, the oxidation process needed both oxygen and a moist atmosphere, and that heat rendered laccase inactive. Kumanotani and his group[e] have established that the function of laccase is to oxidise the catechols to o-quinones as the first stage of hardening. So far as is known this is the only enzyme-catalysed reaction in the hardening process which then proceeds by the extension of the urushiol oligomers by reaction with o-quinones. At present the process is only understood in general outline.[f]

In China and Japan raw lacquer was stirred in open vessels, often with slight warming, to homogenise it and to evaporate part of the water. The Japanese prepared an alternative form of lacquer, *sugurome*[3] or *kurome*[4], by stirring raw lacquer in open containers at 30–40° for several hours to decrease the water content from 20–30 per cent to about 3–4 per cent. *Sugurome* lacquer reputedly had better handling properties than raw lacquer.

Lacquer making is an excellent example of how a complex chemical reaction can be manipulated at artisan level with great precision, without any idea of the chemistry involved. Yet the artisans precisely recognised the relationship be-

[a] Scott (1), p. 36.

[b] The first literary reference to *yin-shih*[2] occurred in a story related in the *Shih Chi*, ch. 126, p. 3203 about the second Emperor of the Chhin dynasty who desired to lacquer the walls of his city in order to prevent the enemy from climbing over them, but had to abandon the idea due to the difficulty of constructing a shady room large enough to encompass the whole thing. The *Hsiu Shih Lu* (A Record of Lacquer Painting), probably written between +1567 and +1572, was the first text to mention taking measures to keep the humidity levels in the room at appropriate levels, and placing the lacquered objects on shelves to dry, see *Hsiu Shih Lu, chhüan chi*, p. 2a; Satō Taketoshi (1), pp. 249–50. For a recent study of the text of the *Hsiu Shih Lu* see Satō Taketoshi (2).

[c] Smith & Strange (1), p. 575.

[d] Yoshida (1)

[e] Kumanotani (1) and Kumanotani, Katō & Hirosaka (1).

[f] Winter, J. (1), p. 14.

[1] 剔紅 [2] 陰室 [3] 未塗目 [4] 黑目

tween moisture levels and the hardening process from early times. A passage in the *Lü Shih Chhun Chhiu*[1] (Master Lü's Spring and Autumn Annals) of −239 given in an earlier Volume included an important statement worth recalling.[a] 'Lacquer is liquid, water is also liquid, but when you mix the two things together, you get a solid. Thus if you moisten lacquer it will become dry.'

The production of lacquer did not enlarge the Chinese technologists' tool kit, apart from enhancing the understanding of the value of heat for the removal of impurities with skimming and homogenisation. However, it must have helped in furthering the prestige of artisans in Chinese society, making advances possible on other fronts. In later times, Fukien emerged as a centre of excellence for lacquer work.[b] It is surely not a coincidence that Fukien was also a major producer of tea, sugar and paper.

The remarks on hardening associated with moisture in the *Lü Shih Chhun Chhiu* indicated that the Chinese early had methods for hardening lacquer. The summer period would have been the best season for applying lacquer as the high humidity would have ensured success. In later times artisans' realising the connection between moisture and hardening, devised special workshops so that they could work in other seasons as well.

The unique beauty of Chinese lacquerware sparked off a rapid development of indigenous lacquer work in Europe after the +16th century. Though familiar with lacquerware from the Islamic world and India, European artists during the +17th century strove to imitate East Asian craftsmanship, which is amply reflected in the terms '*vernis de la chine*' in France, and 'Japan work' and 'japanning' in England. It seems as though very little, if any, technology was actually transferred as the lacquer-bearing trees common in East Asia did not grow in these parts, and no Chinese or Japanese craftsmen were brought to Europe. These circumstances forced European craftsmen to devise lacquer substitutes, such as shellac and varnish. Since the latex trees did not grow in the Islamic world either, craftsmen there used resin lacquer or lac obtained from the dark red, transparent resinous deposit of many species of insect, especially the *Tachardia lacca* or *Coccus lacca*. Though the Chinese have a clear priority, since Islamic lacquerware is only extant from the +13th century in the Near East, scholars by no means agree on an East Asian provenance.[c] I suggest that as in the case of Europe, the Islamic world may also have imitated the Chinese concept of preserving and decorating wood and other materials, eventually developing a rich, exquisite tradition of their own, after an initial period of imitation.

[a] Vol. 2, p. 72.
[b] For famous workshops of Foochow see China Imperial Maritime Customs (1), vol. 2, pp. 108–9.
[c] Fehervari (1), pp. 152–3.

[1] 呂氏春秋

(vi) *Tea*

Tea is a beverage derived from steeping in water leaves processed from the plant *Camellia sinensis*. Black tea, the most widely consumed form in Western countries, results from the promotion of the oxidation of fresh leaf catechins by atmospheric oxygen through catalysis by leaf polyphenolase.[a] These substances naturally occur in intact leaf, but kept apart by the structure of the plant, are caused to react by maceration. The oxidised leaves are fired at the critical point to kill the reaction, then dried and packed. Green tea, the tea of China and Japan, is processed by heating immediately to remove the oxidising enzymes and to preserve the catechins for further modification by heat. Oolong (*wu-lung*[1])[b] tea is a partially oxidised tea popular in certain parts of China.

Chinese and European writers have left a number of accounts of tea making in China which often confuse the reader with their detail. It is far easier to comprehend what was taking place with a background of the chemistry and technology which was defined earlier in the present century; this distinguished four basic steps:[c]

Withering New growth (flush) consisting of the apical bud and several new leaves were harvested and taken for processing to a place, which in China varied in size from a farmer's backyard to a substantial organisation. The leaf was distributed on mats or trays in thin layers to reduce temperature generated by continued respiration, which if allowed to build up injured quality. After 6–18 hours, moisture content also decreased, the leaves became flaccid, and cell permeability increased. When this stage was reached one could proceed to 'rolling'.

Rolling This so-called rolling operation disrupted cell structure and effected enzyme–substrate contact, and allowed oxygenation to proceed. During the rolling process the broken twisted leaves were covered with juice and oxidation began. Some of the mechanical devices that have been developed in modern China for this process in small-scale operations have been illustrated in an earlier Volume.[d]

Oxidation This step was known in the literature as fermentation until 1901 when research demonstrated that black tea was manufactured by an oxidative process.[e] Air was allowed to diffuse through the macerated leaf kept in layers of 5–8 cm on the floor or in trays; high relative humidity and low temperature

[a] See Vol. 5, pt 4, p. 209 for the close relationship of these reactions to lacquer hardening.

[b] Oolong is the Fukienese reading of the characters *wu-lung* which literally mean black dragon. Dragons being synonymous with snakes in south China, the name reputedly derived from someone finding a black snake coiled around a tea plant, the leaves of which were used to prepare this partially oxidised tea; see Yule & Burnell (1), p. 909.

[c] This exposition relies heavily on Graham (1) and Eden (1).

[d] Vol. 4, pt 2, pp. 273–4 and Fig. 439.

[e] Graham, H. (1), p. 637.

[1] 烏龍

(15–25°C) improved flavour. As the reaction proceeded the leaf colour turned from green to copper, and a pleasant, characteristic aroma exuded. In the words of an authority, 'the proper termination point is determined by the skill of the process supervisor (tea maker) on whose judgement the value of the final product is highly dependent'.[a] Oxidation could take from 45 minutes to 3 hours and was terminated by firing.

Firing In large factories in the 20th-century oxidation was terminated in 20 minutes in a hot air oven with forced circulation, which reduced moisture to 2.5–3.0 per cent. The tea was then graded and packed.

The *Chha Ching*[1] (The Manual of Tea) of +770 by Lu Yü[2] indicated that brick tea was the main form manufactured during the Thang. The leaves were picked, withered for a few hours, then steamed, pounded and pressed into brick moulds.[b] The bricks were hung in a 'drying shed' with a pit in the floor for burning wood and charcoal; the resulting dried bricks being the article of trade. With brick tea in the Thang, provided the steaming was adequate, we are looking at the rapid production of a green tea with minimal technological control, but with a big artistic component which resulted in great variation of quality. We have an exact analogy in the first step of sugar preparation where juice, from pounded stalks of sugarcane, was dried on a mat in the sun. A certain amount of mechanisation accompanied the progression of the technique. In a previous Volume the large number of water-driven mills for pounding and rolling tea on the rivers of Chiang-Hsi during the Sung dynasty has been documented.[c] These could have been used for the production of brick tea or powdered tea during the Sung. The technology for tea as it is known in the West, came into being, so to speak, during the Ming. In most accounts the withering process was described by noting the flaccidity of leaves. The rolling and fermentation processes were highly variable, and usually not sharply distinguished. Rolling was undertaken by such diverse means as walking on the leaves, rubbing with the hands, rolling with hand- and water-powered rollers and edge-runners. Maceration varied from gentle rubbing to complete disintegration into small sections that could be rolled into balls. At the appropriate stage the rolled, oxidised leaves were fired. Subsequent treatment was highly variable. The leaves may have been fired, and rubbed between firings for a further one or two times. In small-scale operations rolled, oxidated leaves were given an initial firing before being packed for delivery to merchants, who

[a] *Ibid.*, p. 638.

[b] Steaming is used to kill the enzyme in modern green tea production outside China, but China itself has retrogressed to dry heat, see Graham, H. (1), p. 639. Francis Ross Carpenter translated the relevant section of the Thang text, the *Chha Ching*, as, 'All there is to making tea is to pick it, steam it, pound it, shape it, dry it, tie it and seal it.' See Carpenter (1), p. 70. However, in his own explanation of the techniques of making brick tea in the Thang, Carpenter unfortunately omitted the critical steaming operation (Carpenter (1), p. 24).

[c] Vol. 4, pt 2, p. 398.

[1] 茶經 [2] 陸羽

fired them again, perhaps twice, before cleaning, grading and packing them for export overseas.[a] These secondary firings probably served two functions. First, they brought out distinctive organoleptic properties; tea contains over 300 individual aromatic compounds.[b] Second, repeated firing probably proved necessary to bring down the levels of pathogens and moisture for long sea voyages. In the organisation of the industry, with merchants collecting leaves in the countryside and processing them at centrally located bases, we see great parallels with sugar, which involved collection of raw sugar from farmers and refining for export by merchants. Chinese tea production employed a great number of technologies, from edge-runners and rollers for maceration, to steaming and heating, to control the critical points in production.

(2) The Chinese Technological Tool Kit

The technology of all the agro-industries we have considered had humble beginnings:

Oil	from simple mashing of oil seeds in a mortar and pestle
Paper	as wrapping to and covering from the paper mulberry bark tree, the renowned *tapa* cloth of the Austronesians
Sugar	as sugarcane juice sun-dried on a mat
Indigo	as air-dried indigo leaves put into water
Lacquer	from crude latex hardened during the monsoon
Tea	from pounded *Camellia sinensis* leaves pressed into bricks.

China was able to advance from this primitive base because of the technological 'tool kit' which other civilisations did not possess, or acquired only later. Let us now explore the contents of the tool kit.

The agricultural tool kit

In our summaries of the agro-industrial crops we have not considered agricultural methods. When progressing from subsistence handicraft to commodity production level, the Chinese had the advantage of a distinctly modern agriculture from about the time of Christ, that remained largely independent of mechanical aids such as the plough (although this was available, and indeed was used). The components of this tool kit included:

adequate soil preparation with a variety of hoes (from the Neolithic)[c]
planting in rows on ridges or in furrows to provide appropriate drainage and access for weed control (from the −3rd century)[d]

[a] See Balfour (1), vol. 3, Tea, pp. 828–36, for an extensive summary of methods of tea production in 19th-century China.
[b] Graham, H. (1), p. 638.
[c] Vol. 6, pt 2, p. 137.
[d] *Ibid.*, p. 105.

seed pre-treatment (from the −1st century)[a] or transplanting (from the +2nd century)[b] to achieve 100 per cent stands
fertilisation (from the −1st century).[c]

These practices ensure the growth of good crops anywhere, and in the 20th century they seem so simple as to appear naïve. Yet, it was the +17th century before field crops began to be planted in rows in Europe,[d] and we show below that a large number of sugarcane fields were still sown broadcast in India during the 19th century. Pre-treatment of vegetable seed to improve germination has been discovered in Europe only recently,[e] and transplanting 'invented' and mechanised for sugarcane in 20th-century Hawaii.[f] The lack of fertilisation for the first few hundred years of sugarcane cultivation in the Caribbean has been well documented, and contemporaries regarded it as an innovation in the +18th century.[g] Chinese agriculture had already assumed distinctly modern features from ancient times, and we will presently show just how far ahead of the Europeans the Chinese were with sugarcane agronomy.

Modifications to the basic methods enabled the Chinese to adapt their agriculture to geographical, ecological and social changes, even to activities begun overseas, especially in South-East Asia:[h]

The Chinese had the mould-board plough from +200 enabling efficient cultivation of larger areas with less manpower than possible with the hoe.[i]
Row planting, one of the significant departures in Chinese agriculture listed above, allowed the mechanisation of weeding with inter-row cultivation by horse hoes or mould boards from the +2nd century.[j]
As population density increased, with resulting pressure on resources, the strategy of intercropping could be applied to sugarcane, indigo and tea (from the +14th century).[k] This was an ancient method possibly dating back to the practice of planting grain crops in between rows of arboreal crops such as the lacquer tree.

The manufacturing tool kit

As with the agricultural tool kit, the manufacturing side had the advantage of early acquisition of such key concepts as extraction, and heat and steaming,

[a] *Ibid.*, p. 247, first indications −1st century, first textual reference +6th century *CMYS*, p. 100 for wet rice and p. 270 for indigo.
[b] Vol. 6, pt 2, p. 279. First textual reference +2nd century *Ssu Min Yüeh Ling*; transplanting must have been used before then.
[c] Vol. 6, pt 2, p. 292.
[d] *Ibid.*, p. 251.
[e] *Ibid.*, p. 248.
[f] Humbert (1), pp. 120–1.
[g] Galloway (4), pp. 99–100.
[h] I take this point up below in the section on the transfer of Chinese sugar technology to East and South-East Asia in the period after the +16th century.
[i] Vol. 6, pt 2, p. 174.
[j] *Ibid.*, p. 310.
[k] Vol. 6, pt 2, p. 432.



Fig. 6. A hand mortar and pestle (*chhu chiu*[1]) and the pedal operated trip-hammer known variously as the *tha tui*[2] or *kang tui*[3]; from the 1959 Chung Hua reprint of the original +1637 edition of the *Thien Kung Khai Wu*, ch. 4, p. 64a

with useful secondary methods like using lime as a reagent, applied where appropriate.

Extraction Most of the agro-industries we have considered included the extraction of a constituent of the feedstock, as seen in oil, fibre and sugar. A large number of extractive devices are discussed in Volume 4, part 2 where they are listed in Table 56.[a] Trip-hammers were essential for making significant quan-

[a] Vol. 4, pt 2, pp. 177–8.

[1] 杵臼 [2] 踏碓 [3] 脚碓

tities of paper, sugar, oil, and brick or powdered tea, and there were basically three types. The pedal-operated pounder (*tha tui*[1], *kang tui*[2]) available from the Han dynasty (see Fig. 6), was a simple machine so appropriate for given situations, that it survived into the 20th century.[a] Water-power was harnessed, possibly as early as the −1st century, to trip-hammers by horizontal water-wheels (*wo-lun*[3]) or to spoon tilt-hammers (*tshao tui*[4])[b] (see Fig. 7). More powerful batteries of trip-hammers (*chi tui*[5], *shui tui*[6]) activated by vertical and horizontal water-wheels, appeared from about +300 (see Fig. 8). This machinery provided a great range of equipment for pulverising feedstocks in every conceivable location and for different levels of output. Water-driven hammers were not available before c. +1000 in Europe, the first textual reference being a water-powered fulling mill of +1088, at Lodi, near Milan.[c] A hand-driven form of the edge-runner with longitudinal travel (*yen nien*[7]), and an animal-driven one with a circular path (*nien*[8]) appeared from about the −1st century, and a water-driven version by the +4th century (*shui nien*[9], *shuang lun shui wei*[10]).[d] The edge-runner has the advantage of being able to adjust the extent of the pressure applied by varying the size and weight of the roller. A small edge-runner can be used to roll tea gently, while a large two-tonne roller can apply maximum pressure to oil seeds and sugarcane stalks. The first instance of water-driven edge-runners in Europe occurred with oil processing in the +11th century at Dauphiné, France,[e] and with sugarcane grinding in an edict of Monreale, Sicily in +1176.[f]

These smashing methods were undoubtedly early allied with the traditional static pressing techniques of wedge and beam pressing. The first full description with sugarcane appeared in the *Thang Shuang Phu* of c. +1154, and included an animal-driven edge-runner in combination with a rope-clutch beam-press. Along with secondary wedge pressing, the technique probably goes back to the large-scale oil presses of the +6th century mentioned in the *Chhi Min Yao Shu*. Earlier we alluded to the issue of whether water-driven edge-runners or trip-hammers were the first equipment of oil extraction during the Thang dynasty. It is obvious that each could yield a result in the double-pressing situation, but

[a] It does not appear in Europe before+ 15th century, *Ibid.*, p. 512.

[b] As stated in Vol. 4, pt 2, p. 392, the first explicit statement of a water-driven trip-hammer appeared in the *Hsin Lun*[11] (New Discourses) of c. +20 by Huan Than[12]. It is identified as driven by a horizontal water-wheel in Vol. 4, pt 2, pp. 377–8. The first textual reference for the spoon tilt-hammer occurred in +1145, but it probably dated back to ancient times, see Vol. 4, pt 2, p. 363. Terry S. Reynolds has advanced the hypothesis of the −1st-century origin. He has called the power of these machines 'Water levers', and suggested that they may be the mechanism referred to in texts such as the *Hsin Lun*, see Reynolds (1), pp. 26–8.

[c] *Ibid.*, p. 82.

[d] Vol. 4, pt 2, p. 199.

[e] Reynolds (1), p. 73.

[f] Ritter (1), p. 402.

[1] 踏碓 [2] 埲碓 [3] 臥輪 [4] 槽碓 [5] 機碓
[6] 水碓 [7] 研碾 [8] 碾 [9] 水碾 [10] 雙輪水碓
[11] 新論 [12] 桓譚



Fig. 7. A *battari* from late 19th-century Japan. Two types of water-powered spoon tilt-hammers, known as *tshao tui*[1], thought to date from the −1st century, but for which the first firm evidence only appeared in China in +1145; from Troup (1), figs. 3a and 3b.

[1] 槽碓

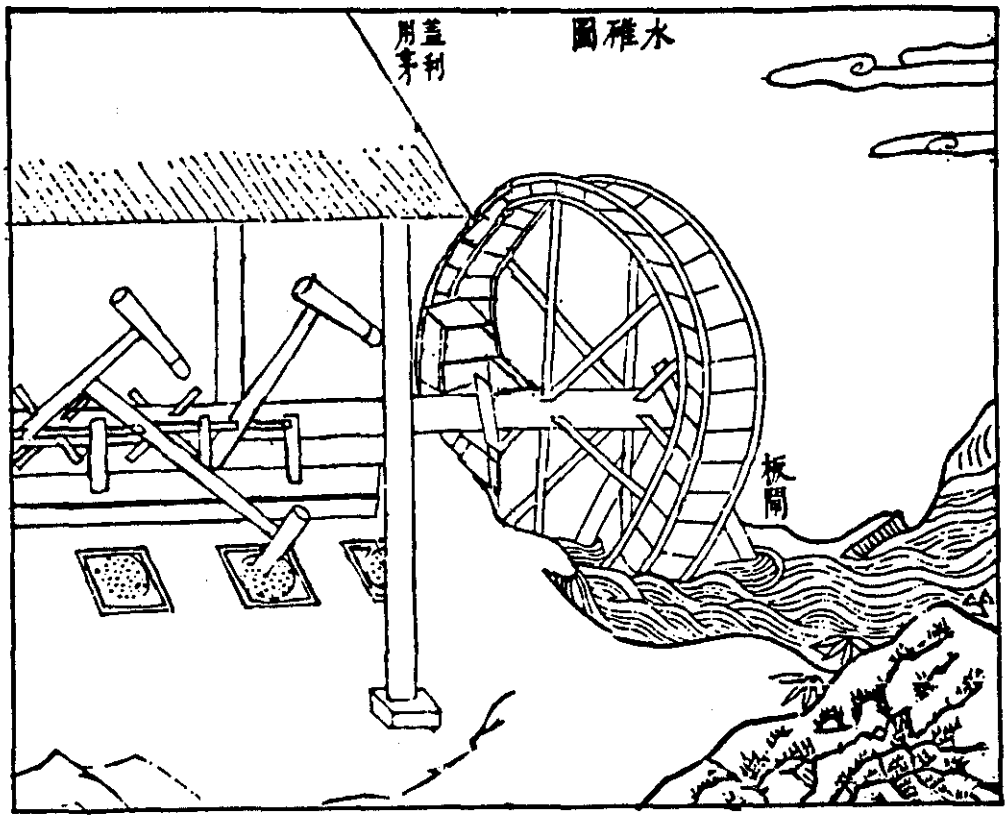


Fig. 8. A battery of trip-hammers powered by a vertical water-wheel. Such trip-hammers performed a wide range of uses; milling flour, polishing rice, macerating fibre for making paper and extracting juice from sugarcane; from the 1959 Chung Hua reprint of the original +1637 edition of the *Thien Kung Khai Wu*, ch. 4, pp. 61b–62a.

the edge-runner had an evident advantage over trip-hammers for the following reason. The edge-runner first extracted oil by its own pressing action, whereas the trip-hammer merely macerated the feedstock for an initial extraction in the secondary pressing operation; the first expressed oil was purer because it remained free of the impurities contained in the lipid organelles that subsequent maceration and pressing extracted.

The question now arises as to the priority and possible transmission of these combined techniques to Europe. A problem of creditability must now be faced because the techniques are so simple. The first part of the process is obvious; anyone who has squashed a nut with a hammer or observed a wheel of a cart run over a sugarcane stalk, has seen the generic technology involved, and secondary pressing appears a logical step to follow on with. Parallel invention may seem feasible. However, the two-stage extraction process detailed in the *Thang Shuang Phu* of c. +1154 does not emerge in explicit form in Islamic civilisation for oil until +1308–9 in Da'ud Al-Antaki's *Tadhkirat Uli al-Albab*...[a] and the

[a] al-Hassan & Hill (1), p. 223.

Nihāyat al-arab fī funūn al-adab of Al Nuwairi (+1279 to +1332), for sugarcane.[a] These datings are certainly conservative, and the earlier mention of large edge-runners in the Dauphiné, France, and Sicily during the +11th and +12th centuries probably signalled the presence of the two-stage process, for a single pressing with an edge-runner would not give full extraction. An examination of the appearance of large edge-runners outside China finds a first dating in a papyrus of +750 to +800.[b] This is most interesting in the light of the history of paper. Paper making is one of the few industries about which no-one disputes the idea of transmission. Paper remained unknown in Europe before the +10th century, but it has been clearly established that China had paper in the Han dynasty at the time of the first trip-hammer, an indispensable machine for making sizeable quantities of paper. The transmission of paper-making technology to Persia is generally agreed to have taken place with the capture of Chinese technicians at the battle of the Talas River in +751. Its movement through Egypt and across north Africa to Spain by the +12th century has not been seriously challenged. I venture the hypothesis that Chinese technicians captured at Talas River also transmitted the Chinese two-stage extraction technology of the large edge-runner with a secondary pressing. This leads us to the conclusion that the Chinese established priority in large-scale oil, sugar and paper technology principally because they possessed water-driven trip-hammers and edge-runners from an early date.

India, where extraction of oil and sugar were probably first mechanised, remained outside these developments as the Indians possessed their own efficient machine, the *kolhu*, an annular mortar and pestle, see Fig. 9. The *kolhu* was such a simple, useful and efficient machine that it survived until the 20th century. However, it could not compete with the two-stage edge-runner static pressing machine when introduced into China and Islamic countries. This point is discussed further below under sugar manufacture.

Heat and steaming Heat was examined in Volume 4, part 1[c] and it was remarked that as in the West there was little theoretical knowledge on the subject, but that Chinese medicinal writings yielded, 'many interesting examples of the observation and uses of thermal phenomena in the technological field'.[d] Agro-industries, in fact, provide numerous examples. Steaming, one of the most effective uses of heat, and a traditional Chinese technique, played an integral part in the two-stage pressing sequence in China. Steam increased fluidity of oil and sugarcane juice, and helped disrupt cellular tissue in oil seeds and parenchyma storage tissues of sugarcane to aid extraction. It also added about 10 per cent moisture which would flush out extra oil and sucrose, and deactivated

[a] See translation in Deerr (1), p. 91.

[b] See Sauvaget (1), pp. 34–6, and Berthier (1), p. 237. Sauvaget considered the equipment in question to be a roller mill, but Berthier (1), p. 237 showed conclusively that it was an edge-runner.

[c] Vol. 4, pt 1, pp. 63–71.

[d] *Ibid.*, p. 63.

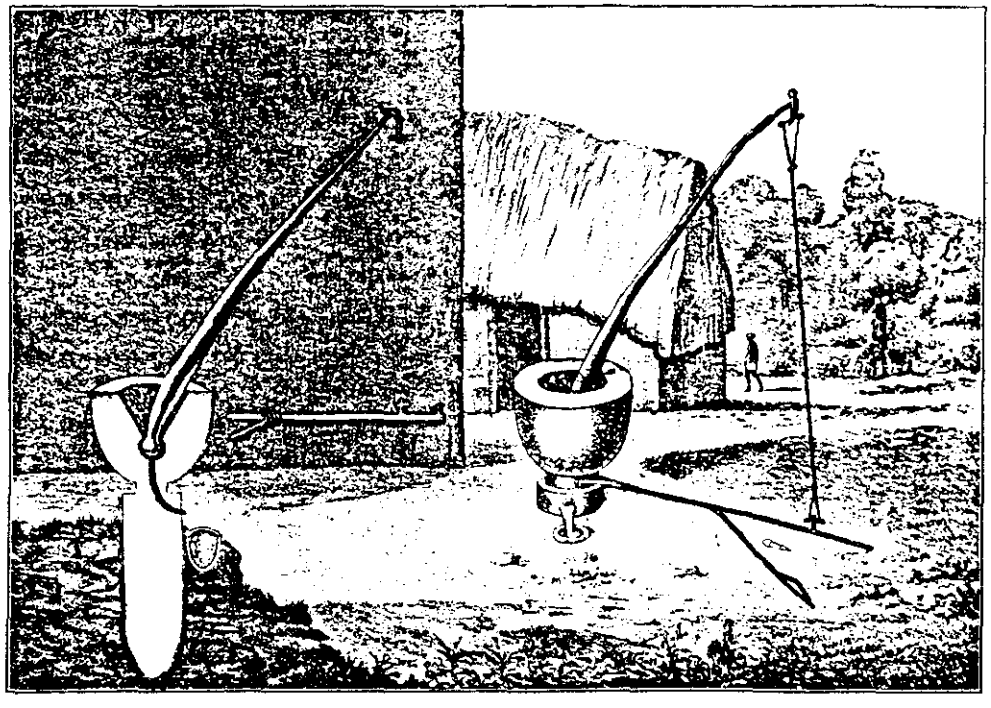


Fig. 9. An annular mortar and pestle from rural India. The illustration includes a vertical section of the machine showing the pestle ball fitting into a cup at the bottom of the mortar beneath which juice flows from an outlet. Pieces of sugarcane 8 to 16 centimetres in length are dropped into the mortar and crushed by the grinding action of the pestle driven by an animal perambulating in a circle. The cane refuse is removed from the mortar by hand; Armstrong (1), p. 12.

the oxidating enzyme polyphenolase in the manufacture of green brick tea. As explained earlier, steam was also used in paper manufacture to help break down fibrous tissue and flush out impurities.

Heat without steaming was most important in the firing process of black tea for stopping enzyme oxidation, enhancing aroma and destroying pathogens. It is all too easy to disregard heat as too commonplace to warrant any comment, but simple heat also promoted the coagulation of colloids, proteins and gums in sugar, lacquer and paper manufacture. The Chinese early displayed an understanding of the value of heat in agro-industrial processes.

Lime as a reagent Lime was a traditional Chinese reagent, its manufacture being described in the *Thien Kung Khai Wu* of +1637.[a] It functioned as a most powerful agent in a number of situations, such as in alchemical ritual,[b] as a third rank of medicine in the *Shen Nung Pên Tshao*[1] of the −1st to +1st centuries,[c] as a wall plaster mixed with clay for granaries[d] and mortar in city

[a] *TKKW*, pp. 283–5.
[b] Vol. 5, pt 4, pp. 289–90.
[c] Vol. 3, p. 43.
[d] Vol. 6, pt 2, pp. 386, 409, and 412.

[1] 神農本草

walls,[a] and in warfare for constructing bombs emitting lachrymatory smoke.[b] In addition, shipwrights mixed it with tung oil to form a putty for caulking boats, a most significant usage for a country with much water-borne traffic.[c] Rudolf Hommel noted lime usage in the preservation of eggs, for tawing skins, and for waterproofing ropes and fish nets, but we possess no data on their history.[d]

The *Chhi Min Yao Shu* of c. +535 carried the earliest known reference to the generic technology of the use of lime in a physio-chemical process:[e]

> In the seventh lunar month dig a pit capable of holding a hundred odd bundles [of indigo stalks and leaves]. Apply a [plaster] of mud and barley bran to a depth of five *tshun*[1] [12.5cm] on [the sides and bottom of] the pit, and cover the four sides of [the top of the pit] with thatch screens (*shan*[2]).
>
> Cut the indigo and invert the stalks [i.e. with the leaves facing downwards] inside the pit. Add water, and use timber and rocks as weights to submerge [the indigo leaves] below water level. In hot weather [let it steep] for one night and in cool weather two nights. Filter off the leaves and stalks, and pour the remaining liquid (*chih*[3]) into an earthenware jar (*wêng*[4]). In general 1.5 *tou*[5] [15.53 litres] of lime are added to an earthenware jar containing 10 *shih*[6] [1,035.5 litres of liquid]. Vigorously beat [the liquid] by hand (*chi shou phêng*[7]) for as long as it takes to eat a meal and then stop (*i-shih chhing chih*[8]). Let the indigo settle to the bottom (*chhêng chhing*[9]), then drain the water off. Dig [another] small pit, and pour the remaining indigo precipitate (*chhu lan thien*[10]) [from the jar] into the pit. Wait until [the precipitate has dried to the state of] thick congee, return it to the jar and the indigo precipitate is complete.

Here lime acted as a precipitating agent, a role which seems to have been restricted to the Chinese cultural area, and proved most effective for controlling critical points in manufacturing processes. Another notable case occurred in paper making, the first full account of which Sung Ying-Hsing gave in his *Thiên Kung Khai Wu*; I have already suggested that lime may have commenced as a macerating agent for bamboo feedstock in the Thang dynasty. Lime also acted as a precipitator (similar to its role in indigo making) in sugar production, and still remains the principal reagent of sugar manufacturing today. Lime clarification was discovered late in sugar boiling, appearing simultaneously in +1637 in the Latin of Angelus Sala's *Saccharologia* and the Chinese of Sung Ying-Hsing's *Thien Kung Khai Wu*, and the ultimate origin remains unknown. We conclude that although lime was available early in China, and was used in some spectacular applications in agro-industries, its application was random over a long period of time rather than systematic.

[a] Vol. 6, pt 3, p. 45.
[b] Vol. 5, pt 7, p. 165.
[c] Vol. 4, pt 3, p. 414, fn. b.
[d] Hommel (1), p. 278.
[e] *CMYS* of c. +535, p. 270; Nishiyama & Kumashiro (1), p. 246.

[1] 寸 [2] 苫 [3] 汁 [4] 甕 [5] 斗
[6] 石 [7] 急手拌 [8] 一食頃止 [9] 澄清 [10] 貯藍澱

Some agro-industries shared similar technologies. For instance, crystallisation played a major part in the manufacture of sugar, salt and saltpetre, and fibre matting in that of paper and felting and the like. Historically speaking these technologies may have developed by interaction between the processing of a number of agro-industrial products, but they did not find wide application and lie outside the scope of this generalised summary.

(3) The Relationship Between Agro-industries and Economic and Social Factors

Though historians of science and technology have examined the agricultural techniques and machinery used in agro-industrial activities, very few have paid attention to their close relationship with the contemporary economic and social situation. This is a shortcoming in view of the fact that these two factors governed to a large extent their technological development. We will frequently have occasion to illustrate the association between technology and economy/society with respect to sugar in the following parts of this study, but first let us briefly consider connections with agro-industries in general.

After the Sung dynasty when agro-industrial production in China rose rapidly, technology influenced the organisation of economic production enabling us to distinguish five main characteristics of agro-industries:

(1) They combined agriculture with engineering, chemical technology and special arrangements for transporting the crop to the processing plant. See Fig. 10 for an example of how an artist has depicted in one scene the growing, processing and packaging of a single crop, tea. The derivation of raw materials from plants and trees dictated that the processing, or at least its initial stages, be conducted relatively close to where they were grown. With crops like tea, indigo and lacquer, the leaves and latex from various places could be assembled in a relatively central location. This stands in sharp contrast to sugarcane crushing, where in many cases after the +16th century roller mills were carried to the field rather than *vice versa*: boats or water-buffalo carts served to transport the equipment from field to field for crushing and initial boiling.

(2) Critical judgement points in both the agricultural and manufacturing processes, along with cleanliness and quality control, were of utmost importance in achieving results in agro-industries. First let us look at critical judgement points. With tea, the correct plucking of the plant had to be performed without bruising. If left too long, the pods of oil-seed plants would shatter and the seeds dissipate. With lacquer high quality latex can only be tapped from the late summer to winter months, and sugarcane only ripened in the autumn–winter period. In the preparation of green oolong and black tea special attention had to be paid at the point when the leaves were fired. In sugar manufacture, the correct deter-

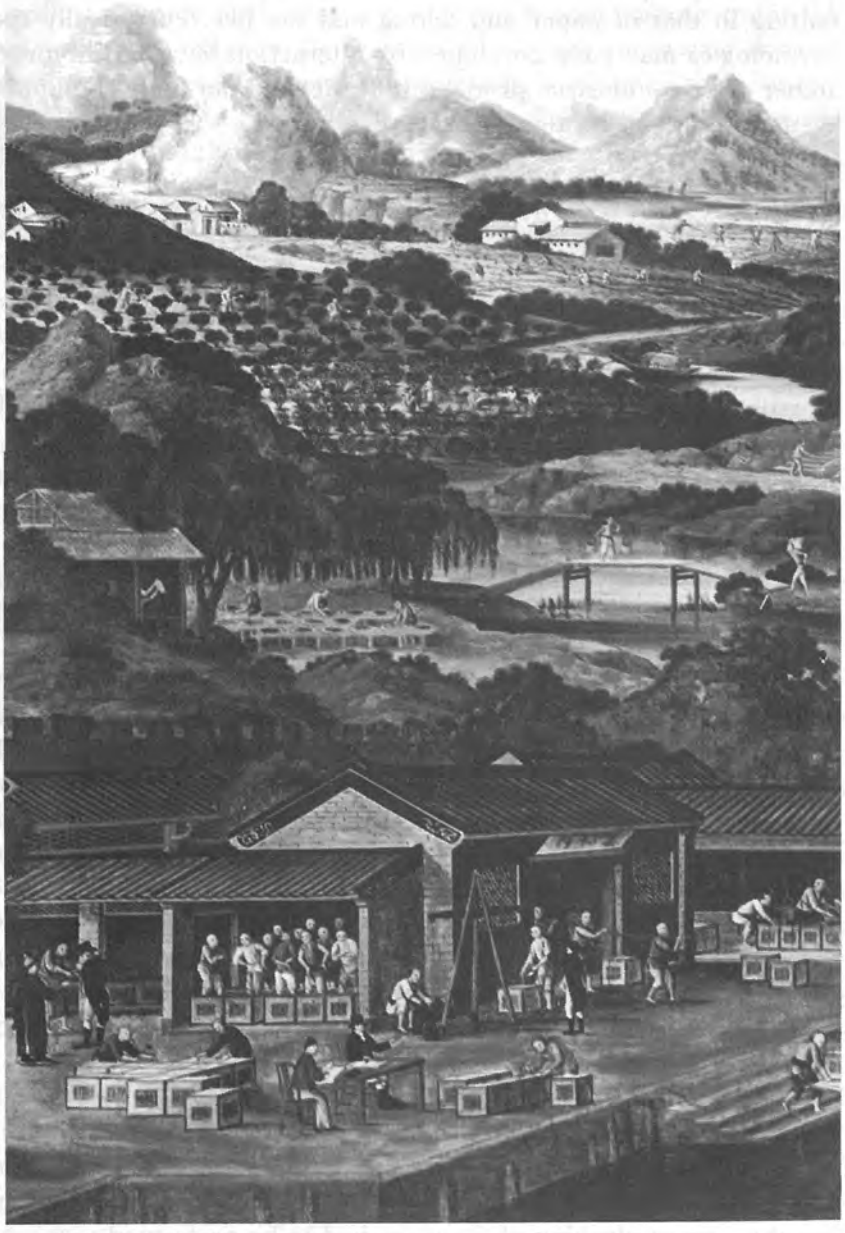


Fig. 10. An +18th-century picture of tea production in China for the European market depicting the integrated nature of agriculture, processing and marketing. In the mountains in the background tea leaves are being picked, then carried by basket to the middle foreground for processing (only drying is visible) and thence to port for packing and sale to European merchants. This is an idealised painting as the tea growing areas were located in Fukien, far away from Canton where the European merchants resided, yet it admirably demonstrated the concept of an agro-industry; from Davidson & Editors of Horizon (1), p. 112.

mination of the point in boiling when sugar will crystallise on cooling was essential for successful production. In indigo processing it was imperative to stop the oxidation reaction at the optimum point; failure to stop the oxidation reaction at the critical point caused the indigo to dissolve into the vat water, thus rendering it unrecoverable. Needless to say, mistakes brought immediate financial loss to the producer. Dependence on human skill to recognise the critical point by necessity created a great deal of variability in the finished article. Robert Mac Micking elaborated on the range of factors influencing the quality of indigo made in the Philippines during the late 1840s:[a]

> To secure a good quality of indigo, great attention must be paid to the clearness of the water, and the proper mixture and quantity of the lime, as too much or too little is equally pernicious; also the time during which the bruising [beating for oxidation] takes place, which, it appears, is a matter of very nice judgement, as it is usual to explain or account for the cause of the bad quality of a lot by saying that the planter has beat it for too long or too short a time and that he did not know exactly when to stop.

Here the author put the need for cleanliness and quality control eloquently.

Artisans aimed to make a commodity of high commercial value, and any misjudgement on their part resulted in monetary loss. The significance of this point can be illustrated in the preparation of the dye known as *sukumo*[1], in Tokushima, Japan, where the indican is oxidised to indigo in the leaf itself, and then pounded to a paste called *aidama*[2].[b] Beds of dried indigo leaves are placed on a clay earthen floor inside a wooden building, in which the air is kept as dry as possible, and water is applied over the hundred-day period of oxidation. After each watering the leaves are turned over by raking and shovelling so as to promote even oxidation throughout the whole leaf-bed. The crucial point is to maintain a constant leaf temperature over the entire hundred-day period, but the sole method of regulation is by adding water to control the rate of the reaction which promotes a considerable quantity of heat. The water master (*mizushi*[3]) relies upon his own intuition (dubbed *kan*[4] in Japanese), cultivated by many years of experience, to decide on the appropriate measures to adopt. He determines the condition of the leaves by examining their colour and appearance with the naked eye as well as by digging a hole in the bed to feel the temperature and texture at the bottom of the bed with his hand. Also, he can tell how the reaction is proceeding by the weight of the leaves when shovelling and raking. Each bed of leaves must be treated separately according to its own peculiarities; some beds generate more, some less heat than others, and therefore

[a] Mac Micking (1), p. 297.

[b] The account of *sukumo* making provided here is based on my field notes of surveys, conducted between 1982 and 1983, of the plant operated by Satō Akihito[5] (1939–) of Itano Gun[6], Tokushima[7], who, aided by his son Yoshiaki[8] (1963–), still employs traditional Edo-period manufacturing methods. Mr Satō the elder has been designated as a Bearer of an Important Intangible Cultural Asset by the Japanese Government.

[1] 菘 [2] 藍玉 [3] 水師 [4] 勘 [5] 佐藤昭人
[6] 板野郡 [7] 徳島 [8] 佐藤好昭

Table 4. *Analysis of three samples of Chinese sugar from Taiwan by the public analyst at Sydney in 1879 at the request of the Colonial Sugar Refining Company of Australia*

	Takao	Taiwan Fu	
	Worst sample	A	B
Cane sugar %	83.36	75.50	68.27
Glucose %	4.06	14.22	16.20
Alkaline salts %	0.54	0.76	1.21
Other salts %	1.62	0.36	1.10
Sand %	0.22	0.12	0.43
Insoluble organic matter %	0.53	0.08	0.21
Albumen and colouring %	2.62	2.36	5.04
Water %	7.05	6.60	7.54
Total	100.00	100.00	100.00
Nett crystallisable sugar [Titre]	73.08	44.02	31.03

Attached to a letter from Grafton Ross to Elles & Co. of Amoy dated 10 April 1879; CSR Deposit 142/3566 65, Archives of Business and Labour, Research School of Social Sciences, Australian National University.

may require more water or fewer straw mats on top to reduce loss of warmth. Water masters regard indigo leaves as living beings, which, like humans, may on occasions catch cold, and they endeavour to treat them with tender love and care. So much depends on their intuitive skill that the possibility for error at any one of the multiple critical judgement points always looms large.

Let us consider another example of the influence of the artisan on quality, this time from sugar production. In Table 4 we reproduce the first-known chemical analysis of Chinese sugar, performed by the public analyst in Sydney in 1879 at the request of the Colonial Sugar Refining Company of Australia. This analysis of three samples of Taiwanese sugar demonstrated a great degree of variation with sugar content ranging from 68.27 to 83.36 per cent, reducing sugars from 4.06 to 16.20 per cent, and with the net titre[a] going from a disastrous low of 31.03 to 73.08. Taiwan Fu[1] sugar contained much higher levels of reducing sugar glucose and (fructose), ash content, and more moisture than Takao[2] sugar, indicating that the former was harder to crystallise than the latter. This difference may have arisen for a number of reasons. First, the operators could have processed immature sugarcane. Second, higher levels of alkaline salts in Taiwan Fu sugar suggest that it was poorly drained in the cones in comparison to Takao sugar. Third, there may have been long delays and little atten-

[a] 'Net titre' is a term used in sugarmaking which deducts the impurities from sucrose because they impede refining. The empirical formula is sucrose−(reducing sugar + ash × 5). Titre is from the French word meaning strength, so net titre is net strength after deducting impurities.

[1] 臺灣府 [2] 打狗

tion to hygiene between cutting and crushing, and between crushing and boiling to heavy syrup, leading to the inversion of sucrose into glucose and fructose. Whatever the reason, here we draw attention to the large variation in quality of sugar attributed to operator efficiency in areas no more than thirty to fifty miles apart.

Lack of uniform quality was a common feature of agro-industrial products, especially in times of expanding production when necessity caused large numbers of ill-trained artisans to try their hand. In short, to achieve good results proven methods and quality control were essential.

(3) Under pre-modern economic and social conditions it proved difficult to combine agriculture with manufacture in vertical integration, thus making intervention by merchants inevitable. There was often a division of labour between a series of individuals or groups, rather than a single individual undertaking all aspects of production. Unlike simple rice farming, it often required more capital and expertise than the ordinary peasant possessed, to undertake both the agricultural and manufacturing processes, without financial and technical assistance from outside. Merchants often engaged in tea processing either by setting up plants themselves, or by providing manufacturers with the necessary finance. Sugar and indigo production were probably the most integrated of all agro-industries because the same peasant could both cultivate and manufacture the crop.[a] The physical requirement of processing these two crops immediately after harvest left little leeway for merchants to intervene in the various stages of processing. In these cases merchant participation remained limited to advancing funds to the immediate producer.[b]

(4) Chinese agro-industries were managerially orientated rather than technologically driven. Continuous technological adaptations were necessary to meet the changes in the economy and environment, as we shall see with the various methods of extracting juice from sugarcane employed from the Thang to the +18th century. In China agro-industries did not rely on slave labour, as in the European sugar and indigo plantations of tropical America. Rather, agricultural production took place for the most part under the landlord–tenant system of land tenure, supplemented by hired skilled labour during the processing season. Merchants or landlords wishing to organise production of a particular

[a] Daniels (*2*), pp. 109–10, and Tajiri (*1*), especially p. 91. Tajiri Tōru makes the point that the technology of the wet method in China required the indigo cultivator to conduct indigo extraction immediately after picking, but that the technique of the method in Japan proved too difficult for growers to master themselves, and a group of artisans were needed. With the wet method delay in immersing the leaves reduced the extraction rate as the indican turned into indigotin which hindered the oxidation of indigo in water. The only example of a division into growers and manufacturers with the wet method comes from early 20th-century Kuang-Hsi, see Tajiri (*1*), p. 100, fn. 42.

[b] For examples of merchants and landlords using tenant and hired labour to grow and manufacture indigo in Kuang-Hsi see Nishikawa (*1*), pp. 162–3.

agro-industrial crop had to work within the framework of this land tenure system. They could either sub-contract agricultural work out to a multitude of peasants and collect the harvested crop for processing in a relatively central location, or they could just maintain control over production by advancing funds to peasants, who undertook the entire agro-industrial operation themselves. The necessity of harvesting the crop at the right time, and being able to recognise the multiple critical judgement points in the manufacturing processes created a need for skilled agriculturalists and artisans. Artisans acquired their skills through accumulated experience, and without them production in many cases was impossible. No matter whether merchants or peasants, all operators had to rely on artisans to a certain extent. Reliance on their skills led to the rise of business management of production at which the Chinese proved themselves extremely adept, especially overseas on the sugar plantations in Java and Sumatra.[a] Failure to select and manage skilled artisans and workers brought financial ruin. It is also apparent from this discussion that agro-industries exerted a profound effect on Chinese society in demanding a cadre of skilled operatives and artisans to keep manufacturing running.

(5) The commercial nature of agro-industrial production encouraged the transfer of both agricultural and manufacturing skills as a technological package within China and overseas. Emigrants from Fukien carried the latest Chinese agricultural and manufacturing techniques for sugar production – the most advanced in the world at the time – overseas as well as to the neighbouring provinces of Chiang-Hsi and Kuang-Tung from the late +16th century. The overseas transfers took place almost concurrently with the domestic ones with the technology reaching the Philippines in the late +16th century, Java, Siam, Taiwan and Vietnam in the +17th century, and Hawaii and the Malay peninsula during the +19th century. Chinese merchants organised Chinese labour to grow sugarcane and managed most of the Dutch sugar estates in Java and Sumatra. Some English abolitionists greatly admired their cultivation techniques for they demonstrated that free men with appropriate equipment, such as the mould-board plough, and cultivation techniques, like furrowing and ridging, worked more efficiently than West Indian slaves with hoes. The Chinese performance in Java was tabled as evidence for the effectiveness of free labour in the British parliamentary hearings against slavery during the late +1790s. The Chinese contribution to agro-industries in Batavia extended to other fields as well. About +1755 they commenced cultivating peanuts for pressing to obtain oil to provide Batavia and the surrounding countryside with lighting fuel. They served as smiths, carpenters, painters, cabinet-makers, *arak* distillers, market gardeners; they grew rice and introduced rice milling equipment, so efficient

[a] See (*f*), below.

that it turned deficits into surpluses.[a] Indeed, Chinese contributions were by no means restricted to Java; they brought a whole host of agro-industrial technologies to many South-East Asian countries as well as to others in East Asia.

On the basis of the above discussion, I suggest that agro-industries are a focal point for exploring the numerous advances obtained across the whole spectrum of Chinese technology. The use of overall Chinese technology is epitomised in sugar making more than in any other branch of Chinese agro-industry; it is one of the few that have continued into the 20th century with ever increasing importance. Since a detailed exposition of six or seven agro-industries would be superficial in the space available, I have chosen to follow the history of sugar, because I believe it the most representative.

By concentrating on a single agro-industry we are able to delve into the agricultural and manufacturing side more deeply than would otherwise be possible. This allows us to make new contributions to our knowledge of the nature of the generic technologies involved, as well to the history of sugar in general. The transfer of Chinese sugar technology overseas from the late +16th century also provides a unique case history for the study of technology transfer, which some investigators mistakenly imply was a 19th/20th century phenomenon. Agro-industries were inextricably connected with the market-place, as was hinted at in our references to their dependence on the technical skills of artisans. The case of sugar shows the interaction between technology and economic factors in China, as many of the techniques employed arose in response to market forces, rather than as abstract ideas of objective technological improvement.

(4) Local Gazetteers as Sources for Agro-industries

Materials for agro-industries basically appear in the same sources as those for agriculture, that is to say, the agricultural treatises, State-commissioned compilations, monographs, pandects of natural history (*pên-tshao*[1]) and other supplementary materials, the nature of which has already been explicated in Volume 6, part 2 and earlier Volumes. Here a brief account of the usefulness of local gazetteers as sources for agro-industries, will be rendered both as general information, and at the same time to provide the reader with some guidance for the following pages on sugarcane and sugar.

The prototype of post-Sung local gazetteers, generally referred to as *fang-chih*[2], or *ti-fang chih*[3], dates back to the *Chou Li*[4] (Records of the Institutions of the Chou Dynasty) and the *thu-ching*[5], or *thu-chih*[6] (literally, illustrated treatises),

[a] Cobban (1), pp. 130–6. The same study showed that the Chinese even supplied Batavia with oysters they raised on beds between +1655 and +1789, *ibid.*, p. 124.

[1] 本草 [2] 方志/方誌 [3] 地方志/地方誌 [4] 周禮
[5] 圖經 [6] 圖志

of the Chhin and Han dynasties. From the Sui–Thang period the illustrated part, originally the central feature of these works, yielded pride of place to more protracted treatises which described specific areas, particularly their geography, rivers, mountains, administrative structure, local customs and festivals, temples and shrines, native worthies, historical sites and other aspects of local affairs beneficial to the operation of government. The terms *thu-ching* and *thu-chih* became less common after the Southern Sung and Yüan dynasties respectively,[a] but that by no means signalled the demise of this genre. Quite to the contrary, the Sung dynasty saw a decided increase in the compilation of such works for political reference with the strengthening of the powers of the central government, and the spread of wood-block printing.[b] For the study of agro-industries, the most important gazetteers emerged after the Sung, particularly those published during the Ming and Chhing dynasties which carry far richer detail about all aspects of local affairs, and are extant in greater numbers than for earlier periods. In his pioneering statistical survey of gazetteers in 1935 Chu Shih-Chia only counted 28 gazetteers extant for the Sung (between +1068 and +1289), and 11 for the Yüan (between +1297 and +1367), but the numbers leapt to 770 for the Ming (between +1368 and +1644), swelled to a staggering 4,655 for the Chhing (between +1644 and 1911), and fell to 368 in the Republican period up to 1933.[c] Since then many more have been found in libraries and collections both within China and abroad; the recent union catalogue of 1985 listed over 8,200 gazetteers for the period prior to 1949.[d] However, one should note that these figures included reprints and a number of works which concerned the same geographical administrative region.

Contemporary administrative divisions served as the basic units for the compilation of gazetteers. On the higher plane stood comprehensive gazetteers, called *i-thung chih*[1], which treated the geographical history of the entire country. The first of these general gazetteers was initiated during the Yüan dynasty, and the Ming succeeded with the printing of the *Ta-Ming I-Thung Chih*[2] in +1461, and the Chhien-Lung[3] Emperor, in the Chhing, published the first edition of the *Ta-Chhing I-Thung Chih*[4] in +1744. On the next plane were provincial gazetteers known alternatively as *sheng chih*[5], *thung chih*[6], or *tsung chih*[7], which began from the Ming. Below this, but vitally important for our purposes, come a group of four which provide the most detailed and precise information available about a local area. First in the administrative hierarchy we find prefectural

[a] Chung-Kuo Fang-Chih Ta Tzhu-Tien Pien-Chi Wei-Yuan Hui (*1*), p. 2. In a personal communication of January 1992 Dr Michael Loewe of Cambridge pointed out that some of the Standard Dynastic Histories included *Ti-li chih*[8], that is lists of major administrative units of the empire, accompanied sometimes by the barest of notes about their features or products, and occasionally by an essay on their administrative history.

[b] For the development of wood-block printing in the Sung, see vol. 5, pt 1, pp. 159–72.

[c] Chu Shih-Chia (*3*), vol. 2, *thung-chi piao*[9].

[d] Chung-Kuo Kho-Hsueh-Yüan Pei-Ching Thien-Wen Thai (*1*), Fan-Li[10].

[1] 一統志 [2] 大明一統志 [3] 乾隆 [4] 大清一統志 [5] 省志
[6] 通志 [7] 總志 [8] 地里志 [9] 統計表 [10] 凡例

gazetteers, *fu chih*[1], followed by sub-prefectural gazetteers, *chou chih*[2], then department gazetteers, *thing chih*[3], and finally on the lowest rung county gazetteers, *hsien chih*[4]. Compilations executed for other minor administrative units included gazetteers for garrisions (*wei chih*[5] or *wei-so chih*[6]), customs barriers (*kuan chih*[7]), townships (*chen chih*[8]) and villages (*hsiang-tshun chih*[9]) along with a whole host of others.[a] According to Chu Shih-Chia county gazetteers occupied 58 per cent of all gazetteers extant for the Ming and 72 per cent for the Chhing,[b] and they remain by far the most numerous category available for reference today, even taking into account all of the new discoveries since the 1930s.

Compilation and publication of local gazetteers had close associations with the State. In +1412 and +1418 the central government put out directives stipulating the format and content of compositions at the prefectural, sub-prefectural and county levels.[c] Inoue Susumu, while conceding that a positive government attitude must have encouraged the compilation of gazetteers to a certain extent, argued that failure to attach high priority to the orders also allowed local officials to ignore them, if it suited them. He noted that though manuals such as the *Fu-Hui Chhuan-Shu*[10] (first published in +1699) prescribed gazetteers as essential reading when assuming new posts,[d] local magistrates probably found them too general in nature for effective use as administrative handbooks, for their main concern centred on more precise and expert matters, namely the dispensation of justice and the collection of tax, for which careful study of the statutes and precedents (*lü-li*[11]) and provincial regulations (*sheng-li*[12]) would have proved more rewarding. In addition to lack of incentive, the average local official had little time to spare for involvement in projects that did not directly advance his own career, and anyway the difficulties in finding funds to cover the printing expenses acted as a further deterrent. Frequent statements, in many gazetteer prefaces, to compilation and printing having to await the arrival of eminent officials (*ming huan*[13]) attest to the general apathy of the ordinary run of bureaucrats. On this basis, Inoue concluded that motivation for the compilation of Ming gazetteers, particularly from the +16th century, originated from the local gentry (*hsiang-shen*[14]), who could not bring their plans

[a] For descriptions of other types of gazetteers see Chung-Kuo Kho-Hsueh-Yuan Pei-Ching Thien-Wen Thai (*1*), pp. 1–9.

[b] Chu Shih-Chia (*3*), vol. 2 *thung-chi piao* gives 444 from a total of 770 for the Ming, and 3,345 from a total of 4,665 for the Chhing.

[c] Phêng Ching-Chung (*1*), p. 298, and these two directives are reprinted on pp. 433–8 of the same work.

[d] In an entry entitled, *lan chih-shu*[15] or reading gazetteers, in the *Fu-Hui Chhuan-Shu*, ch. 3, pp. 12b–13b (pp. 44–5) the author, Huang Liu-Hung[16], stressed the importance of carefully studying gazetteers as a means of getting on with the local people.

[1] 府志 [2] 州志 [3] 廳志 [4] 縣志 [5] 衛志
[6] 衛所志 [7] 關志 [8] 鎮志 [9] 鄉村志 [10] 福惠全書
[11] 律例 [12] 省例 [13] 名宦 [14] 鄉紳 [15] 覽志書
[16] 黃六鴻

to fruition without approval and authority from local officials.[a] In the Ming and Chhing this social group continued to display keen interest in the compilation of gazetteers about their native places, and the names of those specially commissioned to collaborate in the editorial work often appeared in lists given after the preface. In short, the initiation and authorship of local gazetteers owed much to the efforts of the local gentry, many of whom wanted to ensure that their fathers, grandfathers, virtuous female family members and other ancestors got a mention in the biographical sections, but they needed the *imprimatur* of bureaucratic sponsorship to gain the prestige they so desired. This can make the attribution of real authorship difficult to determine. Though prefaces generally register the names of one or more local officials, we can be sure that in most cases these officials merely polished the texts prepared by members of the local gentry. Cataloguers try to get around the problem by listing two or three names and then adding an *et al* (*teng*[1]). Some gazetteers did print the name of the actual composer, but such gazetteers were in the minority.[b]

What are the general contents and the characteristic features of these works? Prolific publication during the Ming and Chhing periods did not turn the basic focus away from local affairs, and gazetteers continued to treat such detailed topics as geographical history, topography, tax revenue, population, markets, irrigation and waterways, military revolts, temples and tombs of celebrities, ancient relics, lists of officials serving in the area along with biographies of chaste women and filial sons. This question is best answered by looking at a concrete example. Table 5, which summarises the table of contents to the +1530 *Hui-An Hsien-Chih*[2], important for its full description of sugar coning and the diffusion process, illustrates the scope of material covered. Of course the arrangement of material and the names in the headings varied from gazetteer to gazetteer; for instance terms regarding the tax system were particularly liable to change with reforms. Local products (*wu-chhan*[3]), sometimes called *thu-chhan*[4], and to a lesser extent, the local customs (*fēng-su*[5]), are by far the most valuable parts for our purposes. The first included information on cultivated crop plants, local wild plants (usually those of use to man), domestic animals, ornithology, zoology and mineralogy, while the second treated the character of the local people, their principal occupations, festivals and habits, and sometimes brief accounts of their seasonal agricultural activities. Much data contained in these two sections cannot be obtained elsewhere, which is what makes them such excellent sources for specific plants and technologies at the local level. The +1530 *Hui-An Hsien-Chih* divides local products into the following sub headings, each of

[a] Inoue (*1*), pp. 1297–306.

[b] The names of the real authors, when given, sometimes appeared on the first page of each *chüan* as in the case of the +1530 *Hui-An Hsien-Chih*, or at the end of each *chüan* in small characters as in the case of the +1697 *Kuang-Tung Thung-Chih*.

[1] 等 [2] 惠安縣志 [3] 物產 [4] 土產 [5] 風俗

Table 5. *Contents of the +1530* Hui-An Hsien-Chih

Chüan 1:	establishment of administration (*chien-chih* 建置), topography (*hsing-sheng* 形勝), boundaries (*fêng-yu* 封域), *li-chia* system (*thu-li* 圖里), fortifications (*hsien-sai* 險塞)
Chüan 2:	mountains and rivers (*shan chhüan* 山川), tides (*chhao-hsi* 潮汐)
Chüan 3:	agricultural land (*thu-thien* 土田), irrigation (*shui-li* 水利), bridges (*chhiao-liang* 橋梁)
Chüan 4:	local customs (*fêng-su* 風俗)
Chüan 5:	local products (*wu-chhan* 物產)
Chüan 6:	population (*hu-khou* 戶口), land tax (*thien-fu* 田賦)
Chüan 7:	commercial taxes (*kho-chheng* 課程), tribute (*shang-kung* 上供), personnel expenses (*chih-fei* 支費), labour service and official service (*chih-i* 職役)
Chüan 8:	public edifices (*kung-yu* 公宇)
Chüan 9:	schools and academies (*hsüeh-hsiao* 學校)
Chüan 10:	temples for sacrificial ceremonies (*tien-tzhu* 典祠), graves (*chhiu-mu* 丘墓), Buddhist and Taoist temples (*tsung-tzhu* 叢祠)
Chüan 11:	officials from other areas (*chih-kuan* 秩官)
Chüan 12	local degree-holders (*hsüan-chü* 選舉)
Chüan 13:	local worthies (*jen-wu* 人物)

which constitutes a category (*shu*[1]) in itself: grains (*ku shu*[2]), vegetables (*shu shu*[3]), trees (*mu shu*[4]), fruits (*kuo shu*[5]), flowering plants (*hua hui shu*[6]), domestic animals (*hsu shu*[7]), birds, beasts, fishes and insects (*niao shou yü chhung chih shu*[8]), commodities (*huo shu*[9]). Most compilations follow this scheme of things, though again they may vary according to time, place and editorial policy.

Many gazetteers merely listed the names of the plants, animals and fish under their respective categories, often citing passages from other works and earlier editions, but some, such as the +1530 *Hui-An Hsien-Chih*, give specific information on individual subjects. For instance, under commodities we find detailed descriptions of the methods of salt making, sugar making, fishing, sericulture, weaving, extraction of dyes from safflowers (*hung hua*[10]),[a] pressing of vegetable oils, iron smelting, burning charcoal and the calcination of oyster shells for lime. The first page of the local products section in this gazetteer bears the name of the author, Chang Yüeh[11], and though the length and thoroughness of the account for each item varies, the style of writing indicates that most of it comes from his own hand. Yet not all gazetteers are like this, and readers should remain alert for odd comments by the compilers scattered among multifarious quotations from all kinds of other works.

Well then how does one distinguish between citations from earlier gazetteers and comments appended by the present compilers? General theory holds that

[a] *Carthamus tinctorius* L. R21.

[1] 屬 [2] 穀屬 [3] 蔬屬 [4] 木屬 [5] 果屬
[6] 花卉屬 [7] 畜屬 [8] 鳥獸魚虫之屬 [9] 貨屬 [10] 紅花
[11] 張岳

material in county and sub-prefectural gazetteers was summarised for inclusion in prefectural compilations, which in turn served as sources for provincial editions.[a] County gazetteers therefore, on the whole, contain the fullest information about their jurisdictions, while that digested in prefectural and provincial gazetteers tends to be summary. Ideally researchers should try to see all extant editions of a gazetteer and compare the texts; this makes it possible to determine whether the facts have been simply copied from an earlier edition or added by the present compilers. This is not always easy for earlier editions may not necessarily be extant, but let us look at a concrete example of how such detective work can be undertaken from my own experience.

In searching for data on the history of paper-making technology in Chiang-Hsi province I came across an important long passage under the local products (*thu-chhan*) section for Kuang-Hsin[1] prefecture in the +1720 *Chiang-Hsi Chih*[2], which the compiler said derived from the *Chiang-Hsi Ta Chih*[3] of Wang Tsung-Mu[4] (+1523 to +1591).[b] Wang Tsung-Mu has his name to two editions of the *Chiang-Hsi Sheng Ta Chih*[5]; did the original source derive from the first one of +1556, or the second one of +1597? After locating the passage in question in *chüan*[6] 8 entitled *Chhu Shu*[7,c] (Book of Paper Mulberry) in the +1597 edition,[d] one wondered whether the same piece appeared in the earlier gazetteer. Since this edition was not held in Japan, the only remaining option was to go to the author's collected literary works, his *Ching-So Wang Hsien-Hsiang Wen-Chi*[8]. Wang must have been proud of his +1556 *Chiang-Hsi Sheng Ta Chih* in seven *chüan* for he included it in this collection.[e] But close inspection revealed that it contained no *Chhu Shu*, so we must conclude that Wang did not write this, and that the co-editor, Lu Wan-Kai[9], must have appended it when he enlarged the second edition. This case demonstrates how supplementary sources can help in dating and verifying the contents of gazetteers.

At this point a few comments on the dating of gazetteers may be appropriate. Many Chinese scholars cite them by the reign period, for example they would

[a] Donald D. Leslie has stated this principle, and my researches confirm the validity of his generalisation, see Leslie (1), p. 72.

[b] +1720 *Chiang-Hsi Chih*, ch. 27, pp. 7b–11b.

[c] *Chhu*[10] was *Broussonetia papyrifera* (R. 597).

[d] +1597 *Chiang-Hsi Sheng Ta Chih*, ch. 8.

[e] The inclusion of local gazetteers in the collections of literary works by scholars during the Ming and Chhing period was by no means standard practice. As Inoue has pointed out (Inoue (1), p. 1290), Chhing literati, in general, held gazetteers in low esteem for they believed that they suffered from serious faults: compilers often lacked learning, made their compilations in great haste, frequently copied material straight out of earlier editions, and on the whole wrote in a dull tone. Needless to say, many prominent intellectuals, for instance the celebrated historian Chang Hsüeh-Chhêng[11] (+1738 to +1801) and the philosopher Tai Chen[12] (+1724 to +1777), found employment on gazetteer compilation projects financed by the gentry for a time, see Elman (1), pp. 134–5.

[1] 廣信(府) [2] 江西志 [3] 江西大志 [4] 王宗沐 [5] 江西省大志
[6] 卷 [7] 楮書 [8] 敬所王先生文集 [9] 陸萬垓
[10] 楮 [11] 章學誠 [12] 戴震

refer to the +1530 *Hui-An Hsien-Chih* as the *Chia-Ching Hui-An Hsien-Chih*[1]. There is a certain logic to this for the actual year of publication generally remains unknown. The only firm date available is that of the preface, yet without further information it remains difficult to prove that printing took place in that same year. Most European scholars, desiring something more precise than the time span of a reign period, which, in the case of the Chia-Ching[2] period, lasted for a full forty-five years, usually refer to them by preface date, as done in this volume. Readers should realise that these merely represent rough dates, with compilation invariably having been undertaken earlier and printing following later.[a]

Compilers would have had little vested interest in making false statements about products in their areas, so we can consider the information reliable and safely assume that local people used the plant crops and processing technologies mentioned. Though officials did not subject gazetteers to the same type of meticulous scrutiny involved in the composition of the standard histories (*cheng-shih*[3]), yet in many respects the material they contain still portrays an orthodox view of contemporary local society, especially the accounts in the biographies. Also, while stressing the importance of grain crops, compilers often appended comments regarding plants and technologies of important agro-industries, and occasionally remarked on the novelty and antiquity of techniques. But omission of such information does not always signify absence, for compilers sometimes deliberately disregarded items that they personally thought insignificant and unsuitable for publication. Nevertheless, on the whole statements may be taken at face value, but it is always better to try to confirm them by comparing accounts of a similar crop or technology given in gazetteers for different areas. For instance, in determining the botanical characteristics of sugarcane clones, as well as for the domestic transfer of sugar-making technology and sugar manufacturing techniques *per se* in this Volume, the accuracy of descriptions has been cross-checked by referring to as many different gazetteers as possible. The results of this study demonstrate that with a few rare exceptions, accounts in these sources generally display a remarkable degree of consistency.

(*b*) SUGARCANE AND SUGAR; CONSUMPTION AND PRODUCTION IN CHINA

In analysing the mass of source materials concerning the economic aspects of the history of sugar in China we have found it helpful to differentiate between

[a] One way of checking preface dates is to look at the sections on natural disasters (*i-pien*[4]) and those on revolts (*ping-pien*[5]) in the gazetteer to see whether any material later than the preface date appears.

[1] 嘉靖惠安縣志 [2] 嘉靖 [3] 正史 [4] 異變 [5] 兵變

consumption and production. Many accounts of pre-modern Asian economic history treat consumption perfunctorily, if at all, on the theoretical assumption that it must have existed for production and trade to expand. But, Sidney Mintz in his book, *Sweetness and Power: The Place of Sugar in Modern History*, has convincingly demonstrated that sugar consumption is a subject well worth studying in its own right. He has provided a fine model for assessing the uses and functions of sugar in European history, which we will review in detail below. Looking at Mintz' ideas from the viewpoint of the history of technology, we find that consumption adds a new perspective to the history of pre-modern economic and technological development. The consumption patterns of various ruling and social classes give us some idea of the qualitative limitations inherent in the economy at particular historical periods. For instance, at a time when sugar was a luxury item, so precious that only the Emperor and aristocrats could afford it, we would naturally assume a small volume of production and little incentive for technological innovation. Yet, as sugar consumption spread to the wealthier merchant and landholder classes, sugar makers adopted new technology to expand production to meet increased demand. J. H. Galloway has argued that the economic rationality of the planter class, the availability of natural resources and the competition in the market-place aided the spread of technological innovations in tropical America (see Galloway (4)). As we shall see later, in China too, the adoption and diffusion of better extraction, clarification, draining and claying technologies constituted one of the pre-conditions for the expansion of sugar consumption and production from the mid-Ming onwards. Therefore consumption, as well as providing us with deeper insight into the social and economic life of the common people, as Mintz so ably demonstrated, also highlights the major role of technology in pre-modern economic development.

In his historical model of sugar consumption Mintz postulated six principal uses or 'functions' in Europe. Sugar began as a medicine, turned into a spice and condiment, then a decorative material, a preservative, a sweetener and finally attained the status of a food (see Table 6). The different uses of sugar, he explained, 'did not evolve in any neat sequence or progression, but overlapped and intersected; that sugar commonly serves more than one purpose at a time is considered one of its extraordinary virtues'.[a] But he conjectured that the major change in the previous pattern of Western European sugar consumption occurred when sugar assumed the role of a food in England from the late +18th century. It was added to porridge, spread on bread in the form of molasses and treacle, used in tea, puddings, pastries, desserts and the like. The rise of sugar as a food for mass consumption only became possible after the five principal uses 'had multiplied, had become differentiated, and were firmly embedded in modern life'.[b] Sugar became a major source of calories for the

[a] Mintz (1), p. 78.

[b] *Ibid.*

Table 6. *The Mintz model of the uses and functions of sugar in European history*

1	*Medicine:* the oldest use, sugar entered Europe via Arabic pharmacology, c. +1000
2	*Spice or condiment:* alters flavour of food, but without clearly sweetening, seasoning food, sauces, pickles etc., c. +1100
3	*Decorative material:* mixed with gum etc., moulded, sculptured, decorated and painted to produce art forms, c. +1500
4	*Preservative:* for curing meat, preparation jam, 'preserved' fruit etc., c. +1500
5	*Sweetener:* the shift from spice to sweetener in Europe was initially related to the import and use of tea, coffee and chocolate, c. +1700
6	*Food or an article of mass consumption:* addition to porridge, spread on bread as molasses and treacle, use in tea, puddings, pastries, desserts and the like, late +18th century

From Mintz (1), p. 78

English working classes, fuelled the human machines of the Industrial Revolution, and thereby reduced the need to produce animal proteins and other foodstuffs; in this sense sugar consumption cut the infrastructure costs of industrialisation. Furthermore, Mintz claimed that sugar in 19th-century England pioneered the principle of the mass-consumption market with which we are so familiar today. Below we apply the Mintz model to China and two things become apparent. First, sugar served a variety of purposes far earlier in China than in Europe. Second, since China never experienced the food stage, a clear pattern of progress leading to that final stage has never manifested itself.

Mintz aimed to understand sugar consumption in Europe, and his model drew on the historical experience of England. Needless to say, this biased it towards Europe and its colonies in tropical America, to the neglect of the rich experience of pre-modern Asia. We have extended the Mintz model to cover non-European civilisations, particularly the sugar-producing regions in Asia, and include sugarcane as well as sugar; to enlarge our vista we must include the basic raw material sugarcane as well as syrups and treacles. Since Europeans for reasons of climate and geography have always only been consumers of the finished product, sugar, and have never adopted the custom of chewing sugarcane, this mode of consumption and its culture has received little attention. Sugarcane functioned as a significant 'sugar' product before the advent of sugar consumption itself, and an understanding of its myriad uses in their social context is most helpful for comprehending the history and development of sugar.

Sugarcane appeared as a significant cultivar throughout Asia and Oceania in pre-historic times. It featured in slash-and-burn shifting agriculture, and garden horticulture associated with staples such as taro and rice.[a] In these situations

[a] Bellwood (1), pp. 136–41 and pp. 142–8; Powell (1), p. 127.

odd plants were mixed in with other cultivars to provide a varied, subsistence food supply. The basic uses of sugarcane included:

1 *Food* Sugarcane was, and still is, used for chewing throughout tropical Asia and Oceania.[a]
2 *Drink* Inhabitants in some areas suffering shortages of fresh water, such as Easter Island and the eastern highlands of New Guinea, used sugarcane juice to supplement sea water or drinking supplies.[b]
3 *Medicine* Special clones were utilised for indigenous medicine.[c]
4 *Ceremonial* Sugarcane and amorphous sugar were presented as a token to honoured guests, as tribute, and gifts.[d]
5 *Magic and religion* Special clones were employed by drive away evil spirits, in love potions and in funeral ceremonies.[e]
6 *Fodder* Chewed up sugarcane, and sometimes sugarcane itself, was fed to pigs and elephants, and the leaves served as cattle fodder.[f]
7 *Thatching* Leaves were used for roofing materials.[g]
8 *Weapons* Sugarcane stalks were sharpened for use as spears in countries such as Fiji.[h]

[a] For the consumption of sugarcane as a food in New Guinea see Powell (1), p. 125. For its exclusive cultivation as a fruit for sale in urban areas, see Watt (1), vol. 6, pt 2, p. 7. Watt estimated that 10 per cent of the sugarcane grown in India was eaten as a fruit. Robert Blust has shown that sugarcane is one of the few cultigens which appear in the inventories of all the Austronesian languages, that is to say the speech of the Taiwanese aborigines, Filipino, Indonesian, Polynesian, Micronesian and Melanesian peoples. See Blust (1) and (2).

[b] For Easter Island see von Humboldt (3), p. 26: 'The natives of Easter Island, who suffer great distress from want of fresh water, drink the juice of sugarcane, and, what is very remarkable in a physiological point of view, like wise sea-water.' In the eastern highlands of New Guinea there are reports of sugarcane used for sustenance under drought conditions, see Daniels, Ashley & Daniels (1).

[c] The first Indian medical treatise, the *Caraka Samhitā* of the +1st or −2nd century listed sugarcane as a medicine, see Shree Gulabkunverba Ayurvedic Society (1), p. 1288. In Powell, Kulunga, Moge, Pono, Zimike & Golson (1), p. 26 it is reported that amongst the Melpa near Mt Hagen, New Guinea sugarcane was considered a healthy food for sick people. In New Britain, Powell recorded the prescription of sugarcane for sore throats, dysentery, diarrhoea and stomach aches see (Powell (1), p. 126 and pp. 143–5). It is interesting that sugarcane should be regarded as a medicament for sore throats as even today heated sugarcane juice is sold on the streets of Taipei, Taiwan as a cure for the same ailment (see Fig. 12 & Fig. 13). In Malaya sugarcane was widely used in medicine as pulp for dressing wounds, as splints for broken bones and in child birth, and cane juice was administered for coughs, while in the Philippines it was given for catarrh, see Burkill (1), p. 1939. Also for Philippines see Bodner & Gereau (1), p. 350 where it is reported that tops of shoots of both *Saccharum sinense* Roxb. and *Saccharum officinarum* L. were 'used in tropical treatment of wounds'.

[d] Austronesian speakers, such as the people of Fu-Nan[1] are well known to have presented sugarcane as ceremonial offerings to the Chinese court, for instance see *NFTMC*, shang, p. 4b. Antonio Pigafetta, the Italian who accompanied the ill-fated Ferdinand Magellan on his voyage to the East Indies between +1519 and +1527, recorded that the Spanish demanded sugarcane from the governor on Palawan Island in the Philippines, see Paige (1), pp. 89 and 103. Sugarcane was important in maintaining good relations between members of a group among the Melpa people, see Telban (1), p. 21. It was widely used in ceremonies in Malaya and Indonesia, see Burkill (1), p. 1939.

[e] For the Malay peninsula see Skeat (1), pp. 237–40, for New Guinea see Powell (1), p. 149, and for Hawaii see Moir (1), pp. 4–5 and Degener (1), p. 58. Degener also recorded that sometimes the dead were embalmed by wrapping the body in sugarcane flowers with *kapa* (*Broussonetia papyrifera* [L.] Vent.) cloth. In Bodner & Gereau (1), p. 350 the use of sugarcane wine from both *Saccharum sinense* Roxb. and *Saccharum officinarum* L., in many Filipino rituals, is reported. George Watt noted that Kāmadeva, the Indian cupid, is sometimes repre-

(cont.)

[1] 扶南

Though the Mintz model missed the types of usages outlined above, it is still important because it emphasised the total cultural experience associated with the consumption of sugar, and not just its value as a food. Here I direct attention to two additional important uses: first, the ceremonial usage of sugar and sugarcane; and second, their wide utilisation in magic and religion. Note also the paradox that in some cultural areas such as south China, where sugar has never been consumed as a 'staple food' in Mintz's sense of the term, sugarcane has remained an important food since prehistoric times.

(1) The Uses of Sugarcane in China

Sugarcane in south China displayed essential uses and functions typical of tropical Asia and Oceania, as it emerged from pre-history. In all these regions it was cultivated either in slash-and-burn regimes, or by rice cultivators in subsidiary mixed gardens. The cultural pattern leading to the advent of the commercial production of sugarcane can be dealt with under the five headings which follow.

(i) *Sugarcane as food, drink and condiment*

Sugarcane has been extensively used for chewing in China since ancient times, and is still consumed in the same way by the Chinese today. It is common to see street vendors selling stalks of sugarcane, and glasses of fresh sugarcane juice crushed on the spot, in the urban areas of south China and Taiwan (see Figs. 11, 12 and 13). Literary references to sugarcane as a food appeared early

Footnotes to page 54 (*cont.*)

sented with his bow made of sugarcane and the string of bees (see Watt (1), vol. 6, pt 2, p. 8). The same source quoted a quaint translation by Sir William Jones:

> He bends the luscious cane, and twists the string,
> With bees; how sweet! but ah! how keen their sting,
> He, with five flow'rets tips the ruthless darts,
> Which through five senses pierce enraptured hearts

The Melpa use sugarcane in a ritual for withdrawing poison from people, see Powell, Kulunga, Moge, Pono, Zimike & Golson (1), p. 26.

[f] Regarding elephants' affection for sugarcane one cannot help but recall the famous Cham adage; 'as well leave a man alone with a girl, as an elephant in a field of sugarcane', see Brodrick (1), p. 264. On the Malay peninsula the juice of the sugarcane clone *tebu betong* was used to make elephants sagacious, see Burkill (1), p. 1939. For sugarcane employed as pig fodder in the Aru Islands located off the south coast of New Guinea see Wallace (1), p. 315. The French traveller and naturalist, Pierre Poivre (+1719 to +1786), who visited Cochin China during the mid +18th century, made the following observation (Poivre (1), pp. 105–6, Eng. version): 'There are two sorts of sugar-canes in this country; the first grows high and thick, the joints at a great distance from one another, the colour always green, the juice plenty, with very little of the salt in it. This species of cane is in general use for feeding and fattening of cattle; and experience teaches them that no sort of food fattens mankind, as well as animals, sooner or better, than this sugar-cane, eat (*sic*) while green, and the sugar which is extracted from it.' Also for sugarcane leaves as horse and cattle feed in +18th century Jamaica, see Edwards (1), vol. 2, p. 226, and for India see Watts (1), vol. 6, pt 2 pp. 7–8.

[g] For Hawaii see Degener (1), p. 58 and p. 269.

[h] Clone Fiji 39, Vasinamoto, collected on Taveuni, Fiji, was sharpened and employed as a spear in warfare, see Daniels, J. (1), p. 1005. 'Vasinamoto' means spear, personal communication from John Daniels, 1988.



Fig. 11. Night stall vendor of sugarcane juice crushed on the spot (*chi-cha chê-chih*[1]) in Hong Kong, January 1990. The vendor crushes peeled short stalks of heated sugarcane in a portable grinder for each customer, and serves the expressed juice in cups; orig. photo Christian Daniels.

in Chinese literature, the best known tale concerning Ku Khai-Chih[2] (+345[?] to +406), who always began chewing a stalk of cane from the less sweet top working down to the sweeter root end so that he might 'gradually enter better realms'. In subsequent literature, and even in speech today, the expression 'better realms' (*chia ching*[3]) is often used figuratively to mean 'paradise'.[a] This

[a] *Chin Shu* ch. 92, p. 2405, Deerr (1), p. 35. The phrase, 'gradually enter better realms', is sometimes translated as 'gradually entering into paradise'. The same story is also quoted in *Shih Shuo Hsin Yü*, see translation in Mather (1), p. 423.

[1] 即榨蔗汁 [2] 顧愷之 [3] 佳境



Fig. 12. A stall vending warm natural sugarcane juice (*jê kan-chê yüan-chih*[1]) in an alley running off Shih-Ta Lu[2] in Taipei, Taiwan, during the winter months. The gas stove over which the sugarcane stalks are roasted is in the foreground. After the sugarcane rind is sliced off with a knife and the stalk crushed in an electric machine, the juice is served to customers in small paper cups, and a tinge of liquid ginger added to prevent colds. Due to the mild winter climate stalls selling cold juice outnumber those vending warm juice; orig. photo Christian Daniels, November 1986.

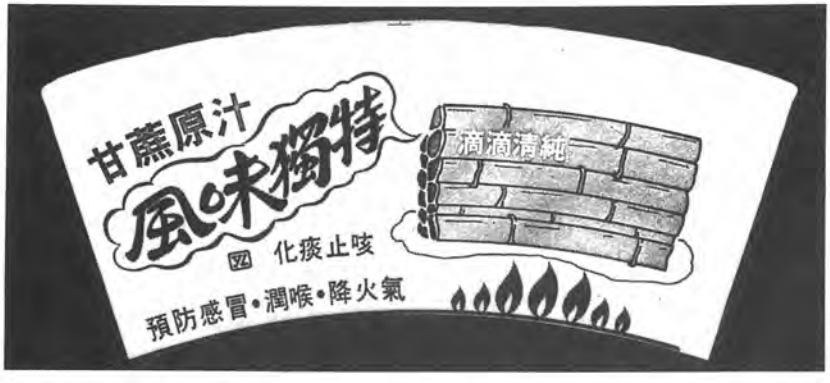


Fig. 13. An advertisement on the side of paper cups used for serving warm natural sugarcane juice (*jê kan-chê yüan-chih*[1]) vended at the street stall shown in Fig. 12. It reads: 'The unique flavour of natural sugarcane juice: every drop pure and clean. Stops the formation of phlegm and coughing, prevents colds, lubricates the throat and relieves burning sensation (*huo-chhi*[3])'; orig. photo Christian Daniels, November 1986.

[1] 熱甘蔗原汁 [2] 師大路 [3] 火氣

brings to mind a passage in the *Pañcatantra* of the +4th century where 'the friendship of the good is compared to a sugarcane, each segment of which below the tip is sweeter than the previous one'.[a]

Sugarcane formed part of the diet of the Yüeh peoples, and Han Chinese immigrants adopted this practice. The first literary reference to sugarcane in Chinese literature appeared in a poem entitled, the Chao Hun[1], or the Summons of the Soul of −241, included in the *Chhu Tzhu*[2] or the Songs of the South where it was mentioned as a condiment for cooking.[b] By the +5th and +6th centuries at least, the Chinese had differentiated in their pharmacopeias between chewing canes, *khun-lun chê*[3], *S. officinarum*, and clones grown for sugar-making, miscanthus cane or *ti chê*[4], *S. sinense*.[c] When chewing canes had to be transported long distances, miscanthus cane was selected probably because of better keeping qualities. In the Northern Sung merchants transported large quantities of miscanthus cane to the Capital, Khai-Feng[5], for sale as a fruit.[d]

Written evidence for sugarcane wine in India emerged in two Hindu medical treatises, the *Caraka Saṃhitā* of the +1st to +2nd centuries and the *Susruta Saṃhitā* of the +4th century.[e] Sugarcane wine (*chê-chiu*[6]), fermented from the juice of sugarcane and sugarcane molasses, appeared quite early in peninsular and insular South-East Asia. The standard history of the Sui dynasty (+581 to +618), the *Sui Shu*[7], reported that the people of the Red Earth Land (*Chhih Thu Kuo*[8]), an Indianised trading State located on the Malaya peninsula, made wine from sugarcane to which they added the roots of a purple gourd (*tzu kua*[9]). The resulting exotic beverage looked, 'yellow-red in colour and the flavour [was] scented and delightful'.[f] Filipinos made an alcoholic beverage from prehistoric times as the Chinese traveller to South-East Asia and the author of the *Tao I Chih Lüeh*[10] (Records of the Barbarian Islands) Wang Ta-Yüan[11] (+1311 to ?) mentioned it on his travels during the +1330s and +1340s. The Jesuit father, Francisco Alcina, in his 'Historia de las Islas e Indos de Bisaya' of +1668 related how the Filipinos adopted the Chinese vertical double-roller sugar mill to extract juice, not for sugar boiling but for making wine.[g] Sugarcane wine was not documented for south China until the +17th century, when writers likened the Chinese brew to its exceptionally sweet counterpart, the

[a] Gopal (1), p. 60.

[b] Tai (1), pp. 6–7.

[c] For *khun-lun chê*, see *Shih Liao Pên Tshao*, and for *ti chê* see *Pên Tshao Ching Chi Chu*, both of which are quoted in the *PTKM*, pp. 1888–9.

[d] *Pên Tshao Thu Ching* cited from the *PTKM*, p. 1889.

[e] Khaviratna (1), p. 293 and Bhishagratna (1), p. 459.

[f] *Sui Shu* ch. 82, p. 1834. Interestingly enough Bodner & Gereau (1), p. 321 writing of Bontoc in northern Luzon have reported the addition of the fruit of *Omalanthus populneus* (Geiseler) Pax to sugarcane wine.

[g] Alcina (1), I: 1: 29. I am grateful to William Henry Scott of Mountain Province, the Philippines, for drawing attention to this source, and kindly rendering the relevant sections into English.

[1] 招魂 [2] 楚辭 [3] 崑崙蔗 [4] 荻蔗 [5] 開封
[6] 蔗酒 [7] 隋書 [8] 赤土國 [9] 紫瓜 [10] 島夷誌略
[11] 汪大淵

celebrated lichee wine (*li-tzu chiu*[1]).[a] Unfortunately the sources are late, and it is impossible to determine when it first began. However, under (iv) Sugarcane in ceremonies, below, we find sugarcane wine associated with offerings to the gods, indicating possible antiquity dating back to Yüeh times.

In summary, sugarcane did not merely serve as a fruit, or as a raw material for processing into sugar, but also as a spice or condiment in cooking. Apart from in Spain and Italy, Europeans did not grow sugarcane and never experienced sugarcane as a food. While the people of China and India have known the taste of sugarcane, syrup and sugar products from ancient times, their counterparts in Europe and North America have only acquired the habit of consuming the finished product, sugar, in recent centuries. Let us examine other aspects peculiar to sugarcane-consuming cultures.

(ii) *Sugarcane as medicine*

Chinese court officials of the − 1st century first documented the medicinal usage of sugarcane, and for a very practical purpose too, the alleviation of the effects of drinking alcohol.[b] Modern research has shown the efficiency of sucrose, glucose and fructose, the major constituents of sugarcane juice, for rapidly metabolizing alcohol.[c] This cure, denied to Europe until recently, was also well known in ancient India appearing in Kalidasa's play *Malavikagnimitra* of c. +375.[d] This knowledge continued in China at least until the 19th century.[e] It is also interesting to note the use of sugarcane to palliate the effects of fish poison. An early +17th-century gazetteer for the island of Hainan prescribed juice obtained by grinding sugarcane, the roots of *lu*[2] (*Phragmites communis* R754) and *kan-lan*[3] (*Canarium album.* Raeusch), for removing toxins from the bodies of people poisoned by eating the globefish (*ho-thun*[4]).[f] This usage most probably derived from the ethnic peoples of south China.

The spread of Buddhism greatly encouraged the consumption of sugarcane in China. Buddhists prescribed syrups and juices as medicines, sometimes numbering as many as fourteen, from a very early period (see Table 7). Their texts, translated into Chinese during the +4th and +5th centuries, expounded the pharmacological properties of the so-called eight juices.[g] In addition, the pharmacopoeias usually carried an entry for sugarcane to accompany the explana-

[a] *THSCL*, p. 57.
[b] *NFTMC*, *shang*, p. 5a and the *Chhien Han Shu*, ch. 23, p. 1063.
[c] Pawan (1).
[d] A line in the *Malavikagnimitra* reads, 'Here indeed is a little healing sugarcane juice for our friend made sick by too much fermented liquor', cited in Deerr (1), p. 49.
[e] For a later example see the 1832 *Shun Chhang HC*, ch. 3, p. 22b.
[f] +1618 *Chhiung-Chou FC*, ch. 3, p. 10a. Also see the +1708 *Chhiung-Shan HC*, ch. 9, p. 27b and the 1857 *Chhiung-Shan HC* ch. 3, *hsia*, p. 55b.
[g] For example, see Taishō no. 1418, p. 1: Taishō no. 1463, p. 843.

[1] 荔子酒 [2] 蘆 [3] 橄欖 [4] 河豚(鮵)

Table 7. *The fourteen juices of Buddhist medicine as known in China*

Chinese	Sanskrit[a]	Botanical Name[b]	English
Kan-chê chiang 甘蔗漿	*Iksu*	*Saccharum officinarum* L.	Sugarcane juice R 756
Shih-liu chiang 石榴漿	*Dādima*	*Punica granatum* L.	Pomegranate juice R 250
Po-lu-sha chiang 波盧沙漿	*Parūsha*	*Grewia subinaequalis* DC.	Dhamin juice
Kho-shu-lo chiang 渴樹羅漿	*Kharjūra*	*Phoenix sylvestris* Roxb.	Wild date juice
Yen-fu chiang 閻浮漿	*Jambū*	*Syzyium cuminii* Skeels.	Rose Apple Tree or Java Plum juice[c]
Pa-chiao chiang 芭蕉漿	*Moca*	*Musa sapientum* L.	Banana juice R 652
An-lo chiang 菴羅漿	*Amra*	*Mangifera indica* L.	Mango juice R 312
Chü-kho chiang 拘柯漿	*Nālikera*	*Cocos nucifera* L.	Coconut juice R 720
Tsao-chiang 棗漿	*Kuvala, Badara*	*Zizyphus jujuba* Mill.	Jujube or Chinese data juice, R 292
Mo-tu-chia chiang 末度迦漿	*Madhūka*	*Madhuca latifolia* Macbr.	Butter tree juice
Phu-thao chiang 葡萄漿	*Drākshā*	*Vitis vinifera* L.	Grape juice R 288
Shê-lou chiang 捨樓漿	*Sāluka*	*Nelumbo nucifera* Gaertn.	Lotus juice
Phu-thi-tzu chiang 菩提子漿	*Bodhivrksa*	*Ficus religiosa* L.	Bodhi-seed juice
Yu-than-po-lo chiang 優曇鉢羅漿	*Udumbala*	*Ficus glomerata* Roxb.[d]	Fig juice R 601

After Maku (*1*), pp. 186–7.
[a] Sanskrit names follow Monier-Williams (1).
[b] Botanical names follow Tanaka, Tyōzaburo (1).
[c] Rose Apple Tree is from Monier-Williams (1), p. 412, and Java Plum from Tanaka, Tyōzaburō (1), p. 712.
[d] R 601 gives *Ficus carica* L.

tion of the therapeutic qualities of sugar. The *Thang Shuang Phu*[1] of c. +1154 claimed the following efficacious effects: 'The pharmacopoeias say that sugarcane dissolves phlegm, quenches thirst, and relieves fevers and headaches (*hsiao than chih kho chhu hsin fan-jê*[2]).'[a] That great compendium of early pharmacopoeias, the *Pên Tshao Kang Mu*[3] of +1596, acknowledged sugarcane as

[a] *TSP* p. 6a; Liu & Liu (*1*), pp. 17–18.

[1] 糖霜譜 [2] 消痰止渴除心煩熱 [3] 本草綱目

sweet, non-toxic, capable of replenishing the spleen *chhi* (*phi chhi*[1]), beneficial to the large intestine and thirst quenching.[a] Later pharmacopoeias prescribed alimentotherapeutic uses. For example, the *Shih Chien Pen Tshao*[2], by Shih Chheng-Chin[3], probably of the +17th century, described the preparation of cane juice rice gruel (*kan-che chou*[4]), reputed to cure a number of illnesses:[b]

Pound sugarcane into a juice, boil it with grain (*pa mi*[5]) and make it into a gruel. If eaten on an empty stomach it will cure cough, fever (*hsü jê*[6]), dry mouth (*khou kan*[7]), dry tongue (*shê tsao*[8]), thick and sticky nasal mucus, vomit and various other ailments.

This prescription hints at the complex nature of sugarcane consumption. On the streets of Taipei, Taiwan, heated sugarcane juice is still vended as a cure for sore throats and colds during the winter months today, which attests to its popularity as a medicine among the common people (see Figs. 11, 12 and 13). A more exotic usage can be found in +17th century Kuang-Tung where the thick sugarcane known as *khun-lun chê*[9] served as a splint for mending broken arm bones. It proved so successful that it acquired the appellation *yao-chê*[10], or medicine cane.[c]

Sugarcane lay on the borderline between medicine, food and condiment, but it would seem that it first began as a chewing food, then became a drink and a condiment, and only assumed significance as medicine at a later date. Wherever people cultivated sugarcane as a garden crop in China all uses listed above and below were employed simultaneously. It is difficult to ascertain whether the idea of sugarcane benefiting health derived from the beliefs of the original Yüeh inhabitants, or the Buddhists. Both may have had a part to play, but we can be certain that the Buddhists in their evangelist campaigns in China definitely promoted, and actively encouraged, the use of sugarcane as an article of food, drink and medicine.

(iii) *Sugarcane in religion*

In the Mahāyāna Buddhist literature introduced into China, the Buddha was known as 'King of Sugarcane', 'born of sugarcane' and the like, because he traced his ancestry to the legendary *Iksvāku* (*iksu* means sugarcane), the son of Manu, the first legendary king god.[d] The five medicines allowed to sick monks in traditional Buddhism included sugarcane, syrup and sugar. Yet it appears that the rules were less strict in China than in India. In a Chinese translation

[a] *Hsin Hsiu Pên Tshao*, p. 17.
[b] *Chhuan Chia Pao*, 4 *chi*, ch. 8, p. 16b. This passage does not appear in the *Shih Chien Pên Tshao* compiled by Ning Yüan during the Ming.
[c] *KTHY*, p. 689.
[d] Soothill and Hodous (1), p. 195.

[1] 脾氣 [2] 食鑑本草 [3] 石成金 [4] 甘蔗粥 [5] 八米
[6] 虛熱 [7] 口乾 [8] 舌燥 [9] 崑崙蔗 [10] 藥蔗

of the Dharmagupta *Vinaya* of +405, the Buddha permitted monks to drink *kan-chê chih*[1] (sugarcane juice), *hei shih-mi chiang*[2] (black syrup, *phānita*), and to eat *juan-hei shih-mi*[3] (soft black sugar) and other sugar products as well.[a] These injunctions, and the stories of the birth of the Buddha from sugarcane, promoted an awareness of sugarcane, syrup and sugar and their consumption as Buddhism spread in China. The Chinese monk, Chien-Chen[4], on his second attempt at sailing to Japan had eighty bundles of sugarcane, as well as some *shih-mi*[5], cane sugar (*chê-thang*[6]) and honey, stowed aboard his ship which departed from Yang-Chou[7] in +743.[b] Fired with evangelist zeal to spread the gospel of the Buddha, Chien-Chen, old and blind, triumphed over great difficulties only arriving in Japan on his third attempt. The inclusion of sugarcane and a variety of sugar products amongst his paraphernalia plainly indicates that he regarded them as essential items for missionary work and the everyday life of a Buddhist.

The *Chhing I Lu*[8] of +950, related an interesting story, probably from the Thang or Five Dynasties period:[c]

> People inside sugar workshops (*thang fang*[9]) steal sugarcane juice which has not been boiled, fill a bowl and drink it. This article is a meritorious and virtuous syrup (*kung-tê-chiang*[10]).

Viewing sugarcane juice as an article that bestowed merit upon the drinker, would have been an added incentive to increased consumption.

Apart from Buddhist beliefs, there is evidence that the Yüeh attributed religious significance to sugarcane, before the coming of Buddhism. Anderson & Anderson have recorded in modern south China what they call 'the lingering of aboriginal beliefs': 'Sugarcane has a number of religious uses and associations, all of uncertain origin and poorly described in most of the literature. It is used in many rites, usually as a marker of an auspicious occasion of some importance, such as the opening of a temple.'[d] These may be practices lingering over from a time when the Yüeh dominated the area, since sugarcane was not originally a Han Chinese cultigen. Emily Ahern described a religious ceremony to the God, Thi:-Kong[11], undertaken by Han Chinese in Taiwan in which sugarcane sometimes features in addition to raw animal offerings:[e]

> Moving to the top of the hierarchy, the highest god, Thi:-kong[11] receives the most untransformed food on the occasion of elaborate *pai-pai*s[12]: raw fowl . . . and sometimes two

[a] Taishō No. 1428, p. 870; Nanjio No. 1117.
[b] Hanawa (1), ch. 69, p. 5a.
[c] *Chhing I Lu*, pp. 20b–21a.
[d] Anderson and Anderson (1), p. 377.
[e] Ahern (1), p. 168.

[1] 甘蔗汁 [2] 黑石蜜漿 [3] 軟黑石蜜 [4] 鑑眞 [5] 石蜜
[6] 蔗餳 [7] 揚州 [8] 清異錄 [9] 糖坊 [10] 功德漿
[11] 天公 [12] 拜拜

stalks of sugarcane uprooted whole from the ground with roots and leaves still intact, constituting the vegetable equivalent of the whole, raw animal offering.

It is apparent that the sugarcane culture of the ethnic peoples of south China had a religious dimension, as elsewhere in South-East Asia and Oceania, and sugarcane was not purely a later import for agricultural utility by Han Chinese.[a]

(iv) *Sugarcane in ceremonies*

Hsi Han[1] in his *Nan Fang Tshao Mu Chuang*[2] (A Prospect of the Plants and Trees of the Southern Regions) of +304 recorded the kingdom of Fu-Nan[3] submitting sugarcane as tribute in +285.[b] The King of Fu-Nan[3] probably selected this sugarcane as an article of tribute to the Han court on account of its extraordinary size and exotic nature. The *Shih Shuo*[4] (The Talk of the Times) by Liu I-Chhing[5] (+403 to +444) commented:[c]

Fu-Nan sugarcane (*Fun-Nan chê*[6]) has three internodes for every one *chang*[7] (2.45 m),[d] wilts when exposed to the sun (*chien jih chi hsiao*[8]) and breaks when blown by the wind.

Later we find ceremonial type functions inside China. The Wei emperor, Thai-Wu[9], reputedly requested some sugarcane from Sung Hsiao-Wu[10] when attacking Phêng-Chêng[11] in +450,[e] and the *Nan Shih*[12] also mentioned it as a target for archery practice.[f] The *Chhi Min Yao Shu*[13] of c. +535 reported that Yü Tu county[14], located in the south of present day Chiang-Hsi submitted sugarcane to the court for Imperial gratification.[g] It is not clear exactly how the Imperial household consumed this sugarcane, but presumably it was either chewed or the juice drunk, or even employed as a condiment in cooking. Nevertheless, it would seem as though the Emperor on occasions bestowed sugarcane on some of his subjects as a rare and wonderful gift. The Thang Emperor, Tai Tsung[15] who reigned from +763 to +779, bestowed twenty sticks of sugarcane on a certain person named Kuo Fên-Yang[16,h].

[a] Bellwood and others see the ultimate origins of the Austronesian people in south China (see Bellwood (1)). There are no Austronesian-speaking people in south China at the moment. The Austronesian speakers extend from Taiwan through Indonesia to Oceania and the Chams in South-East Asia and the Madagascans in the Indian Ocean.

[b] *NFTMC, shang*, p. 4b.

[c] Cited in *Yüan Chien Lei Han*, ch. 404, p. 5a. This passage is not included in the *Shih Shuo Hsin Yü*.

[d] These internodes are so long that it is either an exaggeration by the author or a mistake in the text.

[e] *Nan Shih*, ch. 32, p. 829.

[f] *Ibid.*, ch. 43, p. 1091.

[g] *CMYS* 92.25.2.

[h] *Chhün Fang Phu, kuo-phu*, ch. 4, p. 14a.

[1] 嵇含 [2] 南方草木狀 [3] 扶南 [4] 世說 [5] 劉義慶
[6] 扶南蔗 [7] 丈 [8] 見日即消 [9] 魏太武 [10] 宋孝武
[11] 彭城 [12] 南史 [13] 齊民要術 [14] 雩都縣 [15] 代宗
[16] 郭份陽

Due to the biases of Chinese writers, early sources only refer to sugarcane in connection with ceremonies related to the Emperor and the aristocrat–literati section of society. This has resulted in little good evidence of sugarcane playing a part in the ceremonies of the common people appearing until quite late, though I surmise that the Han Chinese adopted such practices from the time of their initial contact with the Yüeh peoples. According to the gazetteer of +1610 for Phu-Ning county[1] in the northern coastal area of Kuang-Tung province, stalks of sugarcane, broken into lengths of one *chhih*[2] (0.32 m) or so, were placed in front of ancestral tablets (*phai-wei*[3]) as an offering on the first day of the new year.[a] A 19th-century gazetteer for Kuei-Shan county[4], also in coastal Kuang-Tung, mentioned that on the twenty-third or twenty-fourth day of the twelfth lunar month, before the Chinese New Year, two stalks of sugarcane were placed between the ovens to act as a ladder for the Kitchen God to ascend to Heaven to report on the doings of the family for the last year. They were removed on New Year's Day after he had returned from his mission.[b] The +17th-century work the *Ling Nan Tsa Chi*[5] related that many people in Kao-Chou[6], a prefecture in the south of Kuang-Tung province, left sugarcane wine (*chê chiu*[7]) outside their front gates as offerings to the gods in the spring.[c] These sugarcane-associated customs probably derived from the folk culture bequeathed by ethnic Yüeh peoples to the Han Chinese immigrants to this area.

(v) *Sugarcane as a commodity*

Connections with medicine and religion, and associations with the State as an article of tribute, all worked to promote the increase in sugarcane consumption, and its eventual appearance as a commodity vended on the streets of towns and cities. The rise of urban consumption in the Sung initiated the cultivation of sugarcane as a commodity crop.

Most people are apt to think that sugarcane only became a commodity crop with the growth of sugar production for the market; the presumption holds that the commercial cultivation of sugarcane commenced after the demand for it as a raw material or feedstock for sugarmaking arose. Yet, in pre-modern China no real market for sugarcane as a raw material for manufacturing sugar arose since peasants cultivated sugarcane to crush in sugar mills which they either owned themselves, rented from others, or sold to a merchant at a pre-arranged price. Under such conditions a so-called 'free' market for raw sugarcane in the

[a] +1610 *Phu-Ning Hsien Chih Lueh*, ch. 7, *fêng-su* section, n.p. The *Chiu-Chiang Ju Lin Hsiang Chih*, ch. 3, p. 11b of 1883 described the custom of offering sugarcane wine (*chê chiu*[7]) to the gods to celebrate the lighting of lamps on the eighth or ninth day of the new year, in the Pearl river delta region of Kuang-Tung.

[b] 1886 *Kuei-Shan HC*, ch. 15, pp. 3b–4a.

[c] *Ling Nan Tsa Chih*, p. 26b.

[1] 普寧縣 [2] 尺 [3] 牌位 [4] 歸善縣 [5] 嶺南雜記
[6] 高州(府) [7] 蔗酒

feedstock sense simply could not exist. The semblance of anything like a market for sugarcane as a feedstock did not appear until the +18th and 19th centuries when the sugar market expanded.

The commercial production of sugarcane, as the term is employed here, refers to the cultivation of sugarcane as a fruit or drink for sale principally in urban areas. The Chinese distinguished between sugarcane clones for chewing and sugar making, and notably most references to sugarcane in the pre-Thang era are to the former type. The *Chhi Min Yao Shu* of c. +535, a compendium about operating agricultural estates in north China, recorded the cultivation of chewing cane in Yu-Tu[1] in southern Chiang-Hsi expressly for Imperial use.[a] But I do not believe that this fact alone indicates that sugarcane cultivation has surpassed the level of subsistence agriculture. The reason is that prior to the +7th century the following two important conditions for sugarcane becoming a commodity of importance did not exist: (i) the ability to ship large quantities of sugarcane long distances in fresh condition, and (ii) a commodity market. It should be remembered that though sugarcane and sugar became luxury items coveted by the Emperor, aristocrats and selected notables, such levels of consumption still remained too small to create market-oriented production. Bulk shipping of sugarcane to the north had to await the opening of the grand canal between +605 and +610 at the earliest. During the Southern Sung merchants transported large quantities of chewing cane to the capital, Khai-Fêng. Urban growth during the Sung dynasty probably marked the real beginning of the commercial cultivation of sugarcane for chewing on a sizeable scale. The habit of chewing cane has continued until the present time, as we have already seen.[b]

Next let us consider the agricultural methods that caused chewing cane to remain a subsistence crop until the Sung period. In order to comprehend this point it is first necessary to examine the relationship between Chinese and non-Chinese peoples, and to attempt to understand the type of agriculture practised by the aboriginal inhabitants of the region south of the Yangtse river, and the inability of the Chinese to implant settled agricultural methods on them.

Before the rise of the Chiang-Nan[2] region as a rice-producing area with building of the polders and the introduction of transplanting techniques in the Sung, agriculture in south China largely relied on shifting cultivation techniques of slash-and-burn.[c] Successive Chinese dynasties incorporated most of present-day south China and North Vietnam within their administrative boundaries, and tried to sinicise the local aboriginal tribes. Nevertheless, their

[a] *CMYS*, 92.25.2.
[b] For example the 1819 *Chhao-Yang HC*, ch. 10, *wu-chhan*, p. 3b.
[c] Vol. 6, pt 2, pp. 98–101.

[1] 零都 [2] 江南

efforts seem to have been in vain until the Sung at least. Despite the implementation of a positive policy to sinicise the Yüeh from the early Han dynasty, incessant insurrections and rebellions forced the modification of this policy in +136, and the Han adopted a system of appointing locally born leaders to head the commanderies.[a] With the fall of the Han dynasty, the southern commanderies (*chou hsien*[1]) became virtually independent units,[b] but during the Thang the southern commanderies once again came under the control of the central government, even if only nominally, as the aboriginal tribes strongly resisted with numerous rebellions.[c] The Thang set up nominal prefectures, known as *chi-mi chou*[2] or loose-rein prefectures, in order to pacify the non-Chinese peoples both within and without China. A total of 856 loose-rein prefectures were established with 51 prefectures in the Chiang-Nan circuit[3] which roughly corresponded to the area north of the Nan-Ling[4] ranges, 92 prefectures in the Ling-Nan circuit[5] which extended south of the Nan-Ling[4] ranges, and 261 prefectures in the Chien-Nan circuit[6] which encompassed the sugar-making districts of Ssu-Chhuan. These loose-rein prefectures corresponded to tribal boundaries during the reign of Kao-Tsung[7] (+649 to +683), when the non-Chinese peoples entered formal relations with the Thang. The areas held by large tribes were converted into Chinese governments-general (*tu-tu fu*[8]) with tribal leaders appointed as governor-generals and *tzhu-shih*[9], both of which remained hereditary positions. Tribal leaders often rebelled, and had to be put under the supervision of Chinese governor-generals and protectorate-generals (*tu-hu*[10]) garrisoned in border areas.[d] The loose-rein prefectures were protectorates rather than real Chinese territory, and many of them merely delineated spheres of Chinese influence and non-Chinese areas with which the Thang State maintained intercourse. This is important for it reminds us that the Chi-

[a] Wang (1), p. 25.

[b] Wang discusses the situation about +451, when the Chinese were defeated in the north by the Tho-pa[11], and immigrants moved south into central China and eventually into Kuang-Tung and Fukien (see Wang (1), p. 47): 'This is very important, for until this time Kuang-Tung was mainly populated by ordinary Yüeh people who were gradually adopting Chinese ways while Chinese officials, soldiers and merchants occupied the towns. Fukien had a very small Chinese population inland from Foochow ... It is important to note that both Canton and Hanoi were still little more than large trading settlements under the jurisdiction of the Chinese who collected the taxes and protected the merchants.'

[c] The situation in the far south at this time can be gauged from Edward Schafer's account of the Swatow area, a major sugarcane area after the +18th and 19th centuries (see Schafer (16), p. 30): 'Chhao, further to the east, and closest to the Fukien border, claimed between six and seven thousand Chinese residents in town and country, about half the population of Hsün; it produced bananas, and collected shark skins for sword grips, python bile and sea horses for medicine, onchya for incense, a silvery stone – perhaps muscovite schist – presumably for ornamental purposes, and turtles. This isolated countryside was also ill-famed for its colony of crocodiles. Its life was chiefly on the salt sea, but it had no important port – modern Swatow was not even a dream.'

[d] The above account of the loose-rein prefectures and Chinese control of these regions follows the *Hsin Thang Shu*, pp. 1119–20.

[1] 州縣 [2] 羈縻州 [3] 江南道 [4] 南嶺 [5] 嶺南道
[6] 劍南道 [7] 高宗 [8] 都督府 [9] 刺史 [10] 都護
[11] 拓跋

nese did not exercise absolute control over all the territory within the vast area most historical maps attribute to the Thang, and this was especially true of south China.[a]

Under these political conditions, and in the context of the policy of political conciliation, the Chinese pursued two basic methods of sinicisation. First, they established colonies of aborigines and soldiers on the 'frontiers', to whom they lent ploughs and oxen and seeds, while at the same time employing them in public works projects. Second, officials promoted programmes of academic and agricultural education, and in the last half of the +8th century many Yüeh people received a Chinese education at a special centre in Chhêng-Tu[1] in Ssu-Chhuan.[b] The Chinese authorities encouraged mixed marriages for the same purpose, but these methods had little effect, and numerous rebellions broke out between +623 and +966 after which relative peace ensued.[c] The political conditions and level of education failed to conduce a large-scale transfer of Chinese agricultural techniques to the aboriginal peoples. These social and economic conditions made it difficult for Chinese immigrants to cultivate sugarcane at a commodity level before the Sung.[d]

(2) Patterns of Sugar Consumption in China

The first cane sugar products known to man were heavy syrup, the Indian *phāṇita* which appeared c. −500. Solid amorphous sugar appeared shortly after, again in India (*guḍa*), from whence it spread to South-East Asia, and then to China during the first centuries BC, possibly through the agency of Buddhism or Hindu rulers. Honey and malt sugar provided the Chinese with their main sweeteners before contact with cane sugar. The poem, 'Chao Hun' or Summons of the Soul, included in the *Chhu Tzhu* has the lines, 'Fried honey-cakes of rice flour and malt-sugar sweetmeats'.[e] Prior to the introduction of clarification and sugar crystallisation techniques, sugarcane juice was dried in the sun to make an amorphous sugar (*shih-mi*[2]), a semi-solid substance called *i*[3], due to its similarity with barley sugar made from grains. This is well documented by Hsi Han in his *Nan Fang Tshao Mu Chuang* of +304:[f]

[a] See Kawahara Masahiro (*1*), pp. 83–123 for the case of the two powerful aboriginal tribes in the Ling-Nan region, the Fêng[4] and the Ning[5], with wealth and power bases large enough to keep them free from interference by the Thang State, and at times even managing to defy it.

[b] Schafer (16), pp. 33 and 67.

[c] Wang (1), p. 73 and Schafer (16), pp. 61–9.

[d] Paul Wheatley (see Wheatley (1), pp. 85–7) recorded the extent of sugar trade in Sung China and listed several internal and external market destinations. Apart from the political problems, potential trade routes were rudimentary; it was +728 before there was a road over the Ta-Ling ranges giving easier access to potential northern inland markets.

[e] Hawkes (1), pp. 106–7.

[f] *NFTMC*, *shang*, p. 4b.

[1] 成都 [2] 石蜜 [3] 飴 [4] 馮(氏) [5] 寗(氏)

Sugarcane, *chu chê*[1], is also called *kan chê*[2]. The ones grown in Chiao-Chih[3] have [stalks] ... If you press it and obtain its juice, then leave it in the sun for a few days it forms *i*[2], some people call it *shih-mi*[3].

Malt sugar and honey continued as sweeteners until the 20th century in China, but cane sugar eclipsed them in many parts of China from the Sung dynasty when it became a commodity. Replacement of honey cakes by sugar cakes as a luxury article of food during the Thang dynasty is one of the earlier examples of this trend.[a] The sugar market grew slowly by replacing existing sweeteners as the money economy and commodity markets expanded between the Sung and the Chhing dynasties.

Let us now return to the Mintz model of the development of sugar uses and functions. It can be rearranged to include all sugar-producing and sugar-consuming cultures of the world rather than just Western Europe. I envisage the following schema:

(i) *Medicine*: this usage was a carry-over from sugarcane itself, and sugar constituted one of the five medicines of Buddhism and found extensive application in Indian, Chinese, Arabic and European pharmacology.

(ii) *Ceremonial usage, magic and religion*: sugar was widely employed as tribute to Chinese Emperors, gifts in Europe during the Middle Ages, for welcoming household guests and in annual ceremonies in China, and in Hindu ceremonies throughout India and South-East Asia.[b]

(iii) *Decorative material*: sculpturing of sugar is first recorded in the Arabic world where it probably arose around +1100. In China figures made by crystallising sugar on bamboo slats and sculpting it into animal shapes appeared during the Sung.

(iv) *Spice or condiment*: sugar was utilised world-wide as a flavour enhancer.

(v) *Confectionery*: this is not mentioned as a category by Mintz, but is surely a significant development. It probably arose with the introduction, from India, of new sugar technology during the Thang.

(vi) *Preservative*: preserved fruit and crabs appeared as tribute items during the Thang dynasty, c. +800, while in the West this usage seems to have been associated with the rise of sugar production in Madeira where it was recorded for preserving fruit in the late +15th century.

[a] Schafer (25), pp. 108–9. Schafer related that these sugar cakes were made with sugar brought from Magadha. Sugar as well as sugar-making techniques were introduced from Magadha with the mid +7th-century Chinese missions to India. Undoubtedly the quantities of sugar imported were only small and their use reserved for the Imperial family and aristocrats. These facts suggest a large and sophisticated pattern of consumption of sugar in India. Om Prakash (Prakash (1), pp. 177–8) wrote that the Gupta period was characterised by the increasing disapproval of meat eating, and noted that King Harsha (+606 to +647) prohibited meat eating in Magadha. This would certainly foster a wider vegetarian diet, and new dishes prepared with sugar appeared (see Prakash (1), p. 179).

[b] For India see Watt (1), vol. 6, pt 2, p. 8. Watt mentioned that 'in its unrefined state sugar is used as a votive offering at the shrine of their gods. It is given by inferiors to superiors as a mark of respect.'

[1] 諸蔗 [2] 甘蔗 [3] 交趾

(vii) *Feedstock for other handicraft industries*: examples are wine and building materials.

(viii) *The Mintz model and sugar as a food in China*

Each of these usages is outlined below. Many of them overlap, as in the original Mintz model, but I believe that they indicate the true historical pattern of the development of Chinese consumption.

(i) *Sugar as a medicine*

Earlier we observed how the medicinal qualities of sugar, along with those of sugarcane, were included in the Buddhist literature brought into China during the early centuries of our era, so nothing more need be said here. Probably stimulated by Buddhist influence, sugar appeared in pharmacopoeias such as the *Hsin Hsiu Pên Tshao*[1] of +659,[a] and Japanese monks, or possibly students, visiting China in the +8th century brought it back to the Nara court for use as a medicine.[b] The *Thang Shuang Phu*[2] of c. +1154 offered the following general account of its therapeutic effects as well as detailed information on the ingredients of the medicinal pastries and soups:[c]

Sugar candy (*thang-shuang*[3]) of the present day also has the same [effects] as sugarcane, but it is not known why *sha-thang*[4] brings on congested fluids (*than yin*[5]).[d] [Sugar candy] is made into medicinal soups (*thang*[6]) and cakes (*ping*[7]). The methods [for making them] are appended [here];

Gold-facing soup (*tui chin thang*[8]); [is made by] grinding portions of sugar candy, dry yams [*shan yao*[9]; *Dioscorea opposita* Thumb.] and other things finely.

Phoenix marrow soup (*fêng-sui thang*[10]) [is prepared] by grinding portions of sugar candy, dry lotus seeds [*liên tzu*[11]; *Nelumbo nucifera* Gaertn.) and dry yams. Remove the reddish glumes of the lotus seeds [before using].

Wonderfully fragrant soup (*miao-hsiang thang*[12]) [is prepared] by finely grinding one *chin*[13] [600 grammes] of sugar candy. Separately grind seven *fen*[14] [2.6 grammes] of Mr Wu's ambergris (*Wu shih lung-hsien-hsiang*[15]), and knead it into a cake (*ping-ho chih*[16]).

[In making] cakes with sugar candy, do not [limit] the amount used, but finely grind

[a] *Hsin Hsiu Pên Tshao*, ch. 17 gave therapeutic effects of *sha-thang*[17] and *shih-mi*[18]. See *PTKM*, pp. 1890–2 for other medicinal uses.

[b] A +756 inventory of the list of medicines for distribution to the poor donated by the late Emperor Seibu[19] to the Tōdaiji[20] temple in Nara contained cane-sugar (*chê-thang*[21]) which must have originated from China, see Katsura (*1*), p. 6.

[c] *TSP*, p. 6a; Liu & Liu (*1*), pp. 17–18.

[d] It is interesting that the *Chhuan Chia Pao* 4 *chi*, ch. 8, p. 8b of +1707 warned against overeating white sugar (*pai thang*[22]) as it could cause phlegm.

[1] 新修本草 [2] 糖霜譜 [3] 糖霜 [4] 沙糖 [5] 痰飲
[6] 湯 [7] 餅 [8] 對金湯 [9] 山藥 [10] 鳳髓湯
[11] 蓮子 [12] 妙香湯 [13] 斤 [14] 分 [15] 吳氏龍涎香
[16] 餅和之 [17] 沙糖 [18] 石蜜 [19] 聖武天皇 [20] 東大寺
[21] 蔗糖 [22] 白糖

it. Cut up the flesh of pine nuts [*sung-tzu*[1]; *Pinus sp.*] or walnuts [*hu-thao*[2]; *Juglans regia* R], grind and knead [them in with the sugar candy] until they come to a uniform [consistency] like yoghurt and honey (*su mi*[3]). Remove [the cakes] from the moulds (*shih-mu*[4]) and they are ready [for eating]. Some [cakes] are moulded square, some round and some engraved with figures, you may choose whatever shape you like.

This comprehensive monograph included valuable information on sugarcane clones, agriculture, crushing with edge-runner mills and specific methods of manufacturing and storing sugar candy during the +12th century. We shall have occasion to return to it continually in our exposition.

The great Chinese naturalist, Li Shih-Chên, in his *Pên Tshao Kang Mu* of +1596, listed similar remedial effects for *sha-thang*[5] and *shih-mi*[6], as well as others, such as removing the effects of alcohol poisoning and benefiting the small and large intestine. He also detailed the proportions of sugar to mix in prescriptions for particular ailments.[a] Modern research has shown that traditional sugar and salt solutions administered by barefoot doctors for oral rehydration after diarrhoea are soundly based.[b]

Local gazetteers also recorded a diversity of therapeutic uses for sugar. For instance, in the Pearl delta and north-eastern Kuang-Tung sugar reputedly gave relief to the poison of bee bites, if applied immediately after infliction.[c] A +18th-century gazetteer for Chhang-Sha prefecture[7] in Hu-Nan listed cane sugar (*chê-thang*[8]) under the category of medicine (*yao chih shu*[9]).[d] Lan Mo[10] in his *Tien-Nan Pên-Tshao*[11] (Yunnan Pharmacopoeia) of +1556 cautioned against over-eating sugar as he claimed it caused fevers.[e] A Chhing writer of the late +17th/early +18th century, Shih Chheng-Chin[12], noted the administration of sugar (*hung thang thang*[13]) mixed in water to women after childbirth.[f] Even today in China, women are served food cooked with *hung thang* for a month after parturition to help them regain their strength. The same author also listed the harmful effects resulting from over-eating sugar, and interestingly enough mentioned damage to the teeth (*to shih sun chhih*[14]), a concern of some European

[a] *PTKM*, pp. 1890–2.

[b] Taylor and Yu (*1*), pp. 187–9.

[c] For Kuang-Tung province see the 1871 *Phan-Yu HC*, ch. 7, p. 2a. (this source noted that toothpaste was also effective for bee bites) and the 1900 *Hai-Yang HC* ch. 8, p. 9a.

[d] +1747 *Chhang-Sha FC*, ch. 36, p. 9a.

[e] This passage only appeared in the Chhing edition, see p. 510. In August 1989 at Khun-Ming, Yunnan, the author was informed that eating too much sugarcane and sugar may bring on the following complaints: (1) toothache, (2) nose bleeding, (3) excess phlegm, and (4) reduced resistance to colds.

[f] *Chhuan Chia Pao*, 2 *chi*, ch. 5, pp. 5a and 24b and 4 *chi*, ch. 8, p. 8b. This text also recorded other medicinal uses, see *Chhuan Chia Pao*, 4 *chi*, ch. 8, pp. 8b–9a, ch. 8, p. 13a, ch. 8, p. 14a, ch. 8, p. 17a, ch. 8, p. 20b. Even in China today, hen's eggs boiled in water diluted with brown sugar (*sha thang*[15]) are taken for breakfast. A Tai[16] nationality official at Ssu-Mao[17], Yunnan in July 1989 informed me that this dish is still served to women after childbirth.

[1] 松子 [2] 胡桃 [3] 酥蜜 [4] 食模 [5] 沙糖
[6] 石蜜 [7] 長沙府 [8] 蔗糖 [9] 藥之屬 [10] 蘭茂
[11] 滇南本草 [12] 石成金 [13] 紅糖湯 [14] 多食損齒 [15] 沙糖
[16] 傣 [17] 思茅

physicians at least from the time of Tabernaemontanus (c. +1515 to +1590), and W. Vaughan's the *Naturall and Artifical Directions for Health* of +1600.[a]

Despite such warnings, sugar retained its therapeutical associations in Chinese culture, a fact verified by the survival of a market for sugar as a medicine, even in the 20th century when Chinese sugars faced serious threats from imported factory sugar. For example, in Ssu-Chhuan during the 1930s *chieh thang*[1] remained unaffected as it was marketed as a medicine.[b] Presumably both physicians and patients believed the foreign article inadequate as a substitute for the genuine native product.

(ii) *Ceremonial usage, magic and religion*

The Chinese court from very early times received tribute offerings of amorphous sugar (*shih-mi*) as well as sugarcane. The king of Nan Yüeh[2] presented *shih-mi* to the Chinese court somewhere between −206 to −195.[c] The Sung Prime Minister, Wang Fu[3] (+1079 to +1126), requisitioned sugar candy fashioned in the shapes of animals and birds from Sui-Ning[4] in Ssu-Chhuan, through the Ying-Fêng Ssu[5], an office he established during the Hsuan-Ho[6] reign period (+1119 to +1125) to handle articles of tribute sent in from the provinces.[d] The Ming State also collected sugar as part of the labour levy tax as we shall presently see. Sugar featured in court-related diplomatic ceremonies as witnessed in the investiture of foreign kings. Chhen Khan[7], one of the Chinese emissaries despatched to invest the Ryūkyū King, Shō Sei[8], in +1534 took five pieces of feast sugar (*hsiang thang*[9]), a tray of honey sugar cake (*fêng thang kao*[10]) and elephant's eye cake (*hsiang yen kao*[11]) along with other articles for use at the rite.[e] Contemporaries evidently thought fancy sugar rare and valuable enough to be included on such occasions.

The common people in China consumed sugar in various forms at observances throughout the year. As I mentioned earlier, on the twenty-third or twenty-fourth day of the twelfth lunar month they offered it as a farewell gift to the Kitchen God (*tsao shên*[12]) when he left to report to the God of Heaven (*Yü Huang Ta Ti*[13]) on the doings of the family during the past year. The earliest reference I have found appeared in the +1585 gazetteer for Chiang-Lo county[14], Fukien which mentioned candied fruits (*thang kuo*[15]) laid out for the Kitchen God near the cooking stove. The author gave the following reason for

[a] *Chhuan Chia Pao*, 4 *chi*, ch. 8, p. 8b and Mintz (1), p. 103.
[b] *Chū Shi Kensetsu Shiryō Seibi Iinkai* (*1*), p. 34.
[c] *Hsi Ching Tsa Chi*, ch. 4, p. 3a, see Tai (*1*) pp. 9–10.
[d] *TSP*, p. 5b. For the Ying-Fêng Ssu see *Sung Hui Yao Chi Kao*, pp. 2450–4.
[e] *Shih Liu Chhiu Lu*, p. 5.

[1] 潔糖 [2] 南越王 [3] 王黼 [4] 遂寧 [5] 應奉司
[6] 宣和 [7] 陳侃 [8] 尚清 [9] 飴糖 [10] 蜂糖糕
[11] 象眼糕 [12] 竈神 [13] 玉皇大帝 [14] 將樂縣 [15] 糖菓

this practise,[a] 'Tradition has it that sugar is used to sweeten the mouth of the [kitchen] God when he is reporting the bad deeds [of the family] in heaven.' Heaven appointed the Kitchen God to oversee family conduct. Residing in the hearth of the home, the cooking stove, his chief duty included apportioning each family member the length of their lives, bestowing wealth and poverty, and reporting to Heaven on their behaviour. Household members bribed the Kitchen God with sugar to turn a blind eye to misdemeanours, and generally give the family a favourable report in Heaven. It would appear that the worship of the Kitchen God may have originated in connection with alchemy in −133.[b] At first malt sugar (*i-thang*[1]) may have been used for this purpose, especially in north China, but cane sugar replaced it in Kuang-Tung and Fukien by the +16th century, if not earlier.[c] The Kitchen God did not demand a specific type of sugar, rather people in their efforts to delight him undoubtedly offered the most fancy confectionery available. Thus we find sugar balls (*thang thuan*[2]) in Fukien,[d] and biscuits and cakes made with sugar, and sugar-coated beans (*thang tou*[3]) in parts of Kuang-Tung.[e] The *Kuang-Tung Hsin Yü* of +1700 specifically stated, 'The Kitchen God is worshipped with offerings of sugar bricks (*thang chuan*[4]).'[f] In north China, however, malt sugar remained in use in some areas, such as Fu-Kou county[5] in Ho-Nan province until the early 20th century at least.[g] This is not surprising as cane sugar was not a product of north China, and had to be imported from south China. Obviously, local preferences and availability encouraged a great deal of regional variety.

Other festive occasions offered opportunities for consuming sugar in various

[a] +1585 *Chiang-Lo HC*, ch. 1, p. 28a.

[b] Doré (1), tome 11, p. 901.

[c] There is evidence in gazetteers that this custom continued right through to the 20th century. Though many of the gazetteers listed below employ the word *i-thang*[1], or literally, malt sugar, it actually referred to cane sugar as most of the areas concerned produced large quantities of cane sugar. For an example of *i*[6], meaning cane sugar, in Kuang-Tung see *KTHY*, p. 690. For Kuang-Tung province see the +1691 *Nan Hai HC*, ch. 6, *fêng-su*, p. 3b (*i-thang*[1]); +1673 *Tê Chhing CC*, ch. 2, p. 11b (*thang kuo*[7]); +1731 *Kuang-Tung Thung Chih*, ch. 51, pp. 4b–5a (*i-thang*[1]); +1746 *Yang-Chiang HC*, ch. 8, *fêng-su*, p. 18b (*hsing-thang*[8]); 1819 *Mao Ming HC*, ch. 7, p. 16a (*che*[9], *thang kuo*[7]); 1822 *Kuang-Tung Thung Chih*, ch. 92, p. 5b (*i-thang*[1]); 1828 *Wan Chou Chih*, ch. 3, pp. 21b–22a (*tang*[10]); 1831 *Hsi-Ning HC*, ch. 3, *fêng-su*, p. 9a (*i-thang*[1]); 1839 *Hsin Ning HC*, ch. 4, p. 12b (*i-thang*[1]); 1888 *Mao Ming HC*, ch. 1, p. 67a (*thang wan*[11] sugar balls). For Fukien see the +1694 *Ou-Ning HC*, ch. 7, p. 32a (*i-thang*[1]); +1713 *Chien-An HC*, ch. 1, p. 15b (*i-thang*[1]). For Chiang-Hsi province see the +1780 *Tê-Hua HC*, ch. 3, fêng-su, p. 4a (*hsing-ping*[12]). For Ssu-Chhuan province see the +1757 *Kuang-Yuan HC*, ch. 7, p. 5a (*i-thang wei-ping*[13]; biscuits made from sugar); +1787 *Chung-Chiang HC*, ch. 1, p. 18b (*i-thang wei-bing*[13]; biscuits made from sugar); +1786 *San-Thai HC*, ch. 4, pp. 17a–17b (*tsao thang*[14]; biscuits made from sugar); 1816 *Hua-Yang HC*, ch. 18, p. 16a (*tsao thang*[14]; biscuits made from sugar); 1817 *Han-Chou Chih*, ch. 15, p. 7b (*thang*[10]); 1873 *Chhêng-Tu HC*, ch. 2, *fêng-su*, p. 4a (*i-thang*[1]); 1920 *Ho-Chhuan HC*, ch. 35, p. 11a (*tsao thang*[14]).

[d] +1636 *Yu-Hsi HC*, ch. 4, p. 18b.

[e] For biscuits and cakes, see the 1883 *Chiu Chiang Ju Lin HC*, ch. 3, p. 13a (made with rice flour and *phien-thang*[15]), and for sugar-coated beans, see the 1830 *Fo Shan Chung I Hsiang Chih*, ch. 5, p. 18a.

[f] *KTHY*, p. 389.

[g] For Ho-Nan province see the 1833 *Fu-Kou HC*, ch. 7, p. 2b and the 1893 *Fu-Kou HC*, ch. 10, p. 4b.

[1] 飴糖　[2] 糖團　[3] 糖豆　[4] 糖磚　[5] 扶溝縣
[6] 飴　[7] 糖菓　[8] 餳糖　[9] 蔗　[10] 糖
[11] 糖丸　[12] 餳餅　[13] 以糖爲餅　[14] 煮糖　[15] 片糖

forms as well.[a] In parts of Kuang-Tung villagers feasted on sugar biscuits to celebrate the Buddha's birthday on the eighth day of the fourth lunar month when his image was bathed (*yü fo*[1]).[b] In the same province sugar constituted an ingredient in the rice cakes known as *tsung tzu*[2], eaten on the fifth day of the fifth lunar month to commemorate the suicide of the great Warring States period statesmen Chhü Yüan[3] (−343 to −277).[c] People ate moon cakes (*yüeh-ping*[4]) made with sugar at the mid-autumn festival on the fifteenth day of the eighth lunar month,[d] along with *ma-thang*[5], biscuits and preserved fruit such as *chhêng-thang*[6].[e] At the *chung-yang* festival[7], on the ninth day of the ninth lunar month, people would climb to high places and eat cakes made with sugar, variously dubbed *thang kao*[8] or *chung-yang kao*[9]. This type of sugar consumption was documented from the +17th century, but must have dated from an earlier period.[f] At the winter solstice (*tung chih*[10]) ancestors received offerings of sugar balls (*thang wan*[11]). Similar dainties known as *thang yüan*[12], made from sugar and flour and served in a soup, as are *yüan hsiao*[13] today, were relished on the fifteenth day of the new year.[g] In Hua county[14] near Kuang-Chou at New Year during the +17th century, all classes of people, no matter how poor, indulged in white biscuits (*pai ping*[15]) made with rice and sugar.[h] In some areas custom demanded that the bride's family provide sugar or biscuits and cakes at weddings.[i] Extravagant consumption of candied fruits (*thang kuo*[16]) prevailed on nuptial occasions during the first half of the +16th century, so much so in fact, that it even caused the financial downfall of some families.[j] This case highlights the role of sugar as an expensive luxury item at the time.

[a] Many examples of such usage can be found in overseas Chinese communities. For instance about 1820 George Finlayson observed offerings of fruit, sugar and sweetmeats laid before Chinese altars on the island of Pulo Ubi off the southern extremity of Cambodia, Finlayson (1), p. 84.

[b] For Kuang-Tung province see the +1783 *Nan-Ao Chih*, ch. 10, p. 7b and the 1815 *Chhêng-Hai HC*, ch. 6, p. 14a. Examples of biscuits made from sugar used in ceremonies of various kinds appeared in the 1896 *Ssu-Hui HC*, 1 *pien*, p. 72b.

[c] For Kuang-Tung province see the +1640 *Chao Chhing FC*, ch. 9, p. 39a.

[d] For Ssu-Chhuan see the 1815 *San-Thai HC*, ch. 4, p. 16a.

[e] For Ssu-Chhuan see the 1920 *Ho-Chhuan HC*, ch. 35, p. 10a.

[f] For Kuang-Tung province see the +1687 *Hua HC*, ch. 1, p. 33a. For Ssu-Chhuan province see the 1816 *Hua-Yang HC*, ch. 18, p. 14b.

[g] For Kuang-Tung province see the 1821 *Yang-Chhun HC*, ch. 1, p. 42a, and for Ssu-Chhuan province see the 1873 *Chhêng-Tu HC*, ch. 2, *fêng-su*, p. 4a.

[h] For Kuang-Tung province see the +1687 *Hua HC*, ch. 1, p. 34a and the +1758 *Hsin-Hsing HC*, ch. 27, p. 3b which recorded cakes made from rice flour and sugar presented as gifts to others on New Year's Day.

[i] For Fukien province see the 1835 *Lung-Yen CC*, ch. 7, pp. 5a–6a which mentioned the presentation of *hung-thang*[17] at weddings, and *ma-ping*[18] made from *sha-thang*[19], and *pai-ping*[20] made from *pai-thang*[21] as gifts from the bridegroom's family at marriages.

[j] +1561 *Kuang-Tung Thung Chih*, ch. 20, pp. 10b–11a. Candied fruits also appeared in a similar capacity in the +1673 *Tê-Chhing CC*, ch. 2, p. 11b and the +1687 *Hua HC*, ch. 1, pp. 30b–31a.

[1] 浴佛	[2] 粽子	[3] 楚原	[4] 月餅	[5] 麻糖
[6] 橙糖	[7] 重陽節	[8] 糖糕	[9] 重陽糕	[10] 冬至
[11] 糖丸	[12] 糖圓	[13] 元宵	[14] 花縣	[15] 白餅
[16] 糖菓	[17] 紅糖	[18] 蔴餅	[19] 沙糖	[20] 白餅
[21] 白糖				

(iii) *Sugar as a decorative material*

Moulding sugar into the shapes of trees, animals and castles dated back to at least +990 in Egypt,[a] and was also an old custom in China. The *Kuang-Tung Hsin Yü*[1] of +1700 listed the various shapes of decorative sugars sold on the markets in Kuang-Tung province during the +17th century,[b] 'Feast candy (*hsiang thang*[2]) is moulded into the shapes of foreign pagodas, people, birds and animals. It is used a lot at weddings and funeral ceremonies.' The *Thien Kung Khai Wu*[3] of +1637 confirmed the consumption of feast candy at banquets.[c] Apart from more formal occasions, sugar sculptures enlivened everyday life at festival times, such as the mid-autumn moon festival when children set up sugar pagodas (*thang-tha*[4]) and sugar chickens (*thang-chi*[5]) as offerings in the evening.[d]

The origin of these sugar figures remains uncertain. The +12th-century monograph on sugar candy, the *Thang Shuang Phu*, was the first text to mention sugar sculptured into the shapes of mythical lions and round lanterns.[e] Though Li Shih-Chên in his *Pên Tshao Kang Mu* of +1596 equated feast sugar with lion-shaped sugar (*ni thang*[6]) of the commentary to the *Han Shu* of c. +82,[f] we have found no evidence to indicate the appearance of sugar figures before the Sung. In the *Thang Shuang Phu* it is written that:[g]

> Also, there were clever profiteers who split *Miscanthus sacchariflous* (*ti*[7]) and bamboo, plaited them into the shapes of mythical lions (*suan-ni*[8]) and round lanterns and placed them in jars containing boiled cane syrup (*thang shui*[9]). Sugar candy that crystallised [on the figures] was several times more valuable than ordinary sugar candy. However, the formation [of sugar figures] cannot be guaranteed. Furthermore, [such methods were only employed because the sugar candy makers] feared that they would have nothing to present the sub-prefecture and county officials, if strongly pressed [for exotic shaped sugars]. [These sugar candy figures] have not been made in recent years.

Though the author, Wang Cho[10], claimed a Sung provenance for making figures with sugar candy in Sui-Ning, this was certainly not the first appearance of moulded sugar for the *Tung Ching Mêng Hua Lu*[11] (Dreams of the Glories of the Eastern Capital) of +1148 listed the sale of lion-shaped sugar (*shih tzu thang*[12]) and Western River milk sugar (*hsi chhüan ju thang*[13]) at the night market in Khai-Fêng during the early +12th century.[h]

[a] Deerr (1), p. 92; also see Satô (1), pp. 8–9.
[b] *KTHY*, p. 389.
[c] *TKKW*, pp. 171–2.
[d] For Kuang-Tung province see the +1690 *Hsin-Hui HC*, ch. 5, p. 35b, 1804 *Hsin-Ning HC*, ch. 1, *min-su*, p. 10a (also recorded in the 1839 *Hsin-Ning HC*, ch. 4, p. 11b).
[e] *TSP*, pp. 5b–6a.
[f] *PTKM*, p. 1891; Schafer (16), p. 153.
[g] *TSP*, pp. 5b–6a; Liu & Liu (1), pp. 16–17.
[h] *Tung Ching Mêng Hua Lu*, p. 17.

[1] 廣東新語 [2] 饊糖 [3] 天工開物 [4] 糖塔 [5] 糖鷄
[6] 猊糖 [7] 荻 [8] 狻猊 [9] 糖水 [10] 孟均
[11] 東京夢華錄 [12] 獅子糖 [13] 西川乳糖

A later source, however, suggested that sugar sculptures may have an earlier origin. Lang Ying[1] (+1487 to c. +1566) in his *Chhi Hsiu Lei Kao*[2] (A Draft of the Seven Cultivated Categories) of c. mid +16th century, branded eating feast candy sculptured into the shape of human beings, called *thang-jen*[3], as a sort of cannibalism:[a]

> Confucius says, 'Was not the first person who made wooden figures of men and women to bury with the dead without posterity, because he made them in the shape of men and used [them for burial]?' At present sugar is fashioned into the shapes of men and women and people obtain it for eating. Is it not the same as eating people?

The author, well known to posterity for his frequent misquotations of the classics, here upholds his reputation. It was Mencius[4], and not Confucius[5], who uttered these words. The original reads:[b]

> Mencius says, 'Was not the first person who made wooden figures of men and women to bury with the dead without posterity, because he made them in the shape of men and used [them for burial]. What should be thought of a ruler who caused his people to die of hunger?'

Lang Ying probably objected to human effigies in sugar because of their inauspicious association with the death and hunger of the common people, as is the purport of the original passage in Mencius. Other strict Confucians presumably frowned on them for similar reasons. It is interesting to speculate that in China sculptured sugar may have originated from the custom of burying images of live objects with the dead. If this is the case, we would expect them to appear as burial objects in tombs from the Thang at least, but being perishable the likelihood of finding them in an archaeological dig is very slim.

(iv) *Sugar as a condiment or spice*

Sugar first attained fame as a condiment in the preparation of that renowned delicacy, sugar crabs (*thang hsieh*[6]). The first references to this dish dated from the early +6th century, but it undoubtedly boasts a greater antiquity as the southern regions, from whence it originated, made amorphous sugar from the early centuries of the Christian era. The *Chhing I Lu*[7] (Records of the Unworldly and Strange) of +950 mentioned that the Sui emperor Yang Ti[8] (+604 to +617) enjoyed sugar crabs on a visit to Chiang-Tu[9] in the south.[c] The *Hsin Thang Shu*[10] (New History of the Thang Dynasty) gave it as an article of tribute from Tshang-Chou[11] in Ho-Pei province.[d] The *Chhi Min Yao Shu* of +535, the

[a] *Chhi-Hsiu Lei-Kao*, ch. 18, p. 5a.
[b] My translation from text in Legge (3), pp. 9–10.
[c] Cited in the *Hsieh Lu* of Sun Chih-Lu included in *Chhing Chhüan Pa Shih*, ch. 2, p. 4a.
[d] *Hsin Thang Shu*, p. 1017.

[1] 郎瑛 [2] 七修類藁 [3] 糖人 [4] 孟子 [5] 孔子
[6] 糖蟹 [7] 清異錄 [8] 隋煬帝 [9] 江都 [10] 新唐書
[11] 滄州

early compendium of north Chinese agriculture, elaborated on the preparation of this exotic dish:[a]

In the ninth lunar month obtain female crabs ... Put them into water and be careful not to damage or kill them. After one night their abdomens are cleansed (if left for long they will vomit yellow, which is no good). First boil thin sugar (*po thang*[1]; *thang*[2] is thin malt sugar or *po hsing*[3]) and then put the live crabs into a jar of cooled sugar [syrup] for one night. Boil water pepper [*liao*[4]; *Persicaria hydropiper*, L. R. 573] into a soup and add white salt. It particularly needs to be extremely salty. Wait until [the water pepper soup] cools and then pour half of the liquid into [another jar]. Remove the crabs from the sugar syrup, and place them into the salty water pepper solution (*yen liao chih*[5]) whereupon they die. (It is best to only apply a small amount of water pepper. Too much of it will cause [the crabs] to rot.) Then seal the top of the jar with clay (*ni fêng*[6]).

Twenty days later remove them, lift up the abdomen (*chhi*[7]) of the crabs, apply [dry] ginger (*chiang-mo*[8]) and return them to their original position. Place [the crabs] into the jars [*kan-wêng*[9]], a hundred to each container, and pour the [remaining half] of the previous water pepper solution [into each jar] so that it covers [the crabs]. Tightly seal [the jars] ensuring that they are airtight, and [the preservation process] is complete. Contact with drafts is particularly to be avoided for drafts spoil [the crabs] making them unsavoury.

Here sugar functioned as a preservative, as well as a condiment or additive. The eminent Sung scientist, Shên Kua[10] (+1031 to +1095), in his *Mêng Chhi Pi Than*[11] (Dream Pool Essay) of the +11th century, remarked that northerners relished their fish and crabs with sugar and honey (*thang mi*[12]), while southerners preferred salty spicing.[b] Lu Yu[13] (+1125 to +1210) in his *Lao Hsüeh An Pi Chi*[14] (Notes from the Hall of Learned Old Age) of c. +1190 claimed that prior to the Thang dynasty the Chinese preserved crabs and ginger with wine lees, because China did not make sugar prior to that date.[c] The culinary preferences of northerners, coupled with the increasing contact with south and mid-China must have encouraged substitution with sugarcane syrup.

Sources for the Chhing dynasty documented uses. In Hua county[15] near Kuang-Chou, local people flavoured their broad beans (*tao tou*[16]; *Canavalia ensiformis*, DC, R 376) with sugar sauce (*thang chiang*[17]) during the +17th century.[d] The Cantonese also boiled rice-flour dumplings in molasses (*thang shui*[18]) on the win-

[a] *CMYS*, pp. 422–3.

[b] Cited in *Chhing Chhüan Pa Shih*, ch. 4, p. 4b. It is also interesting to note a similar preference among the Vietnamese with respect to fruit. Edward Brown, an Englishman stranded in Cochin China for about a year during the mid 19th century, observed how the Vietnamese 'use salt instead of sugar to give a relish to sour or bitter fruit', see Brown, E. (1), p. 234.

[c] Liu Shu-Khai & Huang Yün-Men (Liu & Huang (2), pp. 31–2) argued that *tsao*[19], the term used for malt sugar, referred to the lees of wine. But I fail to see why the word sugar, *thang*, would be used for an unsweet preservative made with wine lees.

[d] +1687 *Hua HC*, ch. 3, p. 38b.

[1] 薄餳 [2] 餳 [3] 薄餳 [4] 蓼 [5] 鹽蓼汁
[6] 泥封 [7] 臍 [8] 薑末 [9] 堪甕 [10] 沈括
[11] 夢溪筆談 [12] 糖蜜 [13] 陸游 [14] 老學庵筆記 [15] 花縣
[16] 刀豆 [17] 糖醬 [18] 糖水 [19] 糟

ter solstice,[a] and similar uses prevailed amongst Chinese immigrants in Vietnam. For instance, John White, who sojourned in Saigon from 1819 to January 1820, referred to the popularity of molasses as a sauce for pork:[b]

> The Chinese cooks in Onam perambulate the streets with an elastic strip of bamboo across their shoulders, from each end of which is suspended, by cords, a square board, resembling a wooden scale, on which they carry various dishes, ready cooked for the table; among these viands, a very common object is a baked hog, covered with a coat of varnish, made principally of sugar or molasses.

The accomplished Vietnamese scholar and diplomat, Lê Quý-Dôn[1] (+1726 to +1784), mentioned an exotic dish in Thu'ong-Phu'ó'c county[2] called sugar honey dried rice (*dúò'ng mê can phan*[3]) prepared with rice two to three years old.[c]

As is well known the Chinese disdained sweetening their tea with sugar or adding milk. Mintz claimed that this habit originated in Europe and spread to non-European countries after the 19th century, but interestingly enough we have uncovered references to this recent practice in Vietnam close to China in the early 19th century before Western influence became pronounced. John Crawfurd, a visitor to Cochin China during the early 1820s, observed how the Cochin Chinese drank tea 'in large bowls, with or without sugar, and consider it as highly refreshing after fatigue'. This may be due, he surmised, to the fact that the leaf of the tea grown in Cochin China and Tonkin attained a large size, twice that of the bohea tea plant, and unlike Chinese tea had to be boiled to obtain flavour.[d]

(v) *Sugar as confectionery*

Mintz did not treat confectionery as a separate category, but an early appearance in China warrants special attention.[e] Chinese sugar confectionery probably derived from the +7th century when sugar began to replace honey for making sugar cakes as mentioned earlier. The introduction of new sugar-making techniques from India during the +7th century enlarged the quantity of sugar available for confectionery.

The rise of urban markets during the Sung dynasty brought sugar confectionery closer to greater numbers of Chinese than ever before. During the Thang it remained the preserve of the Imperial family, aristocrats, and high officials, but during the Sung confectionery, and indeed other sugar products as well, came within the reach of merchants and other well-off members of society, even if only in small quantities. Sources such as the *Tung Ching Mêng Hua Lu* of +1148,

[a] 1878 *Ting-An HC*, ch. 1, *fêng-su*, p. 4b.
[b] White, J. (1), p. 315.
[c] *Văn Đài Loại Ngũ'*, *quyen* 9, n.p.
[d] Crawfurd (1), p. 477.
[e] In Europe confectionery and preservatives were one and the same in the +18th century. Diderot devoted several plates to *Confiseur*. The confectionery made in the laboratories, as confectionery manufacturing houses were known, included sugar plums, brown almonds, orange slices etc., see Gillispie (1), pls. 480–2.

[1] 黎貴惇 [2] 上福縣 [3] 糖蜜乾飯

and the *Tu Chhêng Chi Shêng*[1] (The Wonder of the Capital) of +1235, which described conditions in Khai-Fêng during the early +12th century and Lin-An[2] (present day Hangchow[3]) in the +13th century respectively, recorded street vendors of all types of confectionery.[a] The *Mêng Liang Lu*[4] (Dreaming of the Capital While the Millet is Cooking) of +1275 mentioned the night stalls of Lin-An[2] vending sugar congee (*thang chou*[5]) along with rich sugar cakes (*fêng thang kao*[6]) and other types of pastries containing sugar as an ingredient.[b] Of course, consumers also prized large crystals of sugar candy as the *Thang Shuang Phu* demonstrated.

During the Ming and Chhing periods the two southern provinces of Kuang-Tung and Fukien consumed considerable quantities of sugar. The *Kuang-Tung Hsin Yü* of +1700 enumerated the great variety of confectionery or fancy sugars eaten in Kuang-Tung province:[c]

> Shops in the market places of Kuang-Tung sell cocoon sugar (*chien-thang*[7]). It is nest silk sugar (*kho-ssu-thang*[8]). That which is boiled down and made into delicate threads (*thiao tzu êrh ling-lung chê*[9]) is called sugar tubes (*thang-thung*[10]). That which is blown and made hollow in the middle is called blown sugar (*chhui-thang*[11]). Small solid ones are called sugar grains (*thang-li*[12]), while the large ones are known as sugar melons (*thang-kua*[13]) [all of these are types of cocoon sugar] ...
>
> Sesame sugar (*chih-ma thang*[14]), cow's hide sugar (*niu-phi-thang*[15] [sugar candy]), excellent sugar (*hsiu-thang*[16]), luxuriant sugar (*tshung-thang*[17]), black sugar (*wu-thang*[18]) and other sugars are taken as snacks (*tsa shih*[19]).
>
> Luxuriant sugar from Chhao-Yang[20] [county, Chhao-Chou prefecture[21]] is extremely white and without impurities. In the mouth it melts as smoothly as snow that has been sprinkled with water.

On the island of Hainan the local people boiled sugar with potato flour to make an appetiser.[d] In Fukien, sugar also featured as an ingredient in recipes for biscuits and cakes. For instance, *sha-thang*[22] was essential for making sesame biscuits (*ma-ping*[23]),[e] and white sugar for baking white biscuits (*pai-ping*[24]).[f] Also Chang-Phu county[25] commanded a good reputation for its brilliant sugar (*ming-thang*[26]), a white sesame-coated biscuit containing white sugar, flour and other ingredients.[g] Nan-Ping county[27] also boasted cakes (*kao*[28]) made with sugar and wild jujubes (*suan tsao*[29]; *Zizyphus. vulgaris*, Lam. R. 294).[h]

[a] *Tung Ching Mêng Hua Lu*, p. 17 and *Tu Chhêng Chi Shêng*, pp. 91 and 94.
[b] *Mêng Liang Lu*, p. 243, p. 245 & p. 269.
[c] *KTHY*, p. 389.
[d] 1892 *Wu-Chhuan HC*, ch. 2, pp. 9b-10a.
[e] 1835 *Lung-Yen CC*, ch. 7, p. 6a
[f] *Ibid.* For similar uses in Kuang-Tung province see 1871 *Phan Yü HC*, ch. 6, p. 9b.
[g] +1700 *Chang-Phu HC*, ch. 4, p. 3a.
[h] 1872 *Nan-Phing Hsien Chih, wu-pu*, ch. 1, p. 10b.

[1] 都城紀勝	[2] 臨安	[3] 杭州	[4] 夢粱錄	[5] 糖粥
[6] 豐糖糕	[7] 繭糖	[8] 窠絲糖	[9] 條子而玲瓏者	[10] 糖通
[11] 吹糖	[12] 糖粒	[13] 糖瓜	[14] 芝麻糖	[15] 牛皮糖
[16] 秀糖	[17] 蓉糖	[18] 烏糖	[19] 雜食	[20] 潮陽
[21] 潮州府	[22] 沙糖	[23] 藏餅	[24] 白餅	[25] 漳浦縣
[26] 明糖	[27] 南平縣	[28] 糕	[29] 酸棗	

This volume of evidence suggests considerable consumption of confectionery, especially considering the claim for a county in +18th century Kuang-Tung, 'It is a custom to use sugar (*thang*[1]) to accompany tea (*chha phin*[2]).'[a] This statement and similar ones, however, need to be qualified. The Chinese have never indulged in English style morning and afternoon teas or desserts; they never changed their basic diet to accommodate sugar as a food. In short, sugar consumption in China did not presage or follow the path towards everyday usage paved by England after the advent of the Industrial Revolution. Rather consumption in China centred around special festive occasions, or for offering guests with tea.

(vi) *Sugar as a preservative*

This category is not well documented in either the East or the West, but preserved fruit and crabs appeared in tribute items during the Thang dynasty as indicated earlier. In the West, preservatives seem to have been associated with the rise of sugar production in Madeira, where preserved fruit is recorded in the late +15th century. In China, however, the candying of fruits gained popularity from the Sung at least, and has remained common until the present day.

During the Sung, sources, such as the *Tu Chhêng Chi Shêng, Mêng Liang Lu* and *Wu Lin Chiu Shih*[3] (Institutions and Customs of the Old Capital) of c. +1270, recorded the sale of candied fruit (*thang kuo*[4]), and sugared and honeyed dates (*thang mi tsao êrh*[5]).[b] Han Yen-Chih[6] (+1131 to +1200) in his *Chü Lu*[7] of +1178, a monograph on oranges in Wen-Chou[8], Chekiang, listed medicated bitterpeel tangerines (*yao chü*[9]) cooked with sugar, and smoked sweetpeel tangerines (*hsün kan*[10]) served with a little sugar. This text also indicated that during the +12th century honey remained the preferred method of preserving oranges, with sugar still perhaps a novelty, and definitely not yet the norm:[c]

To preserve the sweetpeel tangerines (*kan*[11]), bitterpeel tangerines (*chü*[12]) and tangerines (*chin kan*[13]) the skin should be slit without separating it from the pulp segments, and by pressing the fruit force out the seeds, after which it should be saturated with honey (*mi*[14]). Tangerines (*chin kan*) preserved in honey are better than other kinds. The local people have a method whereby they boil bitterpeel tangerines with sugar and call this product medicated bitterpeel tangerines (*yung thang ao chü chê yao chü*[15]). This is mixed with a small quantity of ashes of rushes and placed in a cauldron. When the colour turns black it can be kept for a long time. If the bitterpeel tangerines (*chü*) fruit is a little damaged, remove the skin and bake the fruit in an oven putting it through a

[a] For Kuang-Tung province see the +1731 *Chieh-Yang HC*, ch. 4, *wu-chhan*, p. 50b.
[b] *Tu Chhêng Chi Shêng*, p. 91 & p. 94; *Mêng Liang Lu*, p. 243, p. 269; *Wu Lin Chiu Shih*, p. 444.
[c] *Chü Lu, Hsia*, pp. 3b–4a. Translation slightly revised from Hagerty (1), p. 95.

[1] 糖 [2] 茶品 [3] 武林舊事 [4] 糖果 [5] 糖蜜餳兒
[6] 韓彥直 [7] 橘錄 [8] 溫州 [9] 藥橘 [10] 熏柑
[11] 柑 [12] 橘 [13] 金柑 [14] 蜜 [15] 用糖煮橘者藥橘

kind of smoking process. This product is called smoked sweetpeel tangerines (*hsün kan*), and if served with a little sugar or honey (*thang mi*[1]) the flavour is excellent.

Until the +12th century at least, honey remained the dominant preservative for oranges, sugar being reserved for processing bitterpeel tangerines.

As Montgomery Martin, an English visitor to China during the 1840s after the first Opium War noticed, the Chinese candied a great variety of fruits and vegetables: *Ko* hemp (*ko*[2]: *Pueraria hirsuta* Schneid. R406) commonly known as *thang ko*[3],[a] winter melons (*tung-kua*[4]: *Benincasa cerifera* Savi. R56),[b] watermelons (*hsi-kua*[5]: *Citrullus vulgaris* Schrad. R57),[c] canton oranges (*chheng*[6]; *Citrus aurantium* L. R343),[d] cumquats (*chin chü*[7]: *C. Japonica*, Th. R345),[e] bitterpeel tangerines (*chü*[8]; *Citrus nobilis*, Lour. R347),[f] sweetpeel tangerines (*kan*[9]; *Citrus noblis*, Lour. R348),[g] plums (*mei*[10]: *Prunus mume*, S. et Z. R447),[h] the Buddha's hand (*hsiang yuan*[11]: *C. medica*, L. R346a),[i] peanuts (*lo hua sheng*[12]: *Arachis hypogaea* L.),[j] betel (*chü chiang*[13]: *Piper betle*, L. R628),[k] and others.[l]

The *Kuang-Tung Hsin Yü* of +1700 attested to the widespread consumption of preservative fruit, 'Guests are entertained with candied fruit (*thang kuo*[14]).'[m] Martin also made the following observation:[n]

The Chinese candy almost everything eatable, such as millet-seeds, bamboo-shoots, ginger etc., which are hawked about the streets, and exported to all countries, particu-

[a] For Kuang-Tung province see the 1871 *Phan-Yu HC*, ch. 7, p. 2a.

[b] For Kuang-Tung province see the +1687 *Hua HC*, ch. 3, p. 38b; +1731 *Chieh-Yang HC*, ch. 4, *wu-chhan*, p. 7a; +1763 *Chhao-Chou FC*, ch. 39, p. 6b and +1779 *Chieh-Yang HC*, ch. 7, *wu-chhan*, p. 4b called it *kua-po*[15], or melon amber. The 1815 *Chheng Hai HC*, ch. 23, p. 4b, explained that melon ambers were winter melons glazed with sugar and honey. Also, see the 1892 *Shih-Chheng HC*, ch. 2, p. 36b.

[c] In Kuang-Tung province the +1731 *Chieh-Yang HC*, ch. 4, *wu-chhan*, pp. 7a–7b called candied watermelon *hsi-kua kao*[16] or watermelon cake. Also see +1779 *Chieh-Yang HC*, ch. 7, *wu-chhan*, p. 5a.

[d] For Kuang-Tung province see the +1731 *Chieh-Yang HC*, ch. 4, *wu-chhan*, p. 9b, +1779 *Chieh-Yang HC*, ch. 7, *wu-chhan*, p. 6a.

[e] For Kuang-Tung province see the 1884 *Chhao-Yang HC*, ch. 12, p. 6a.

[f] For Kuang-Tung province see the +1731 *Chieh-Yang HC*, ch. 4, *wu-chhan*, p. 9b; 1900 *Hai-Yang HC*, ch. 8, p. 3a. For Taiwan see the +1764 *Fêng-Shan HC*, p. 289.

[g] For Fukien see the 1873 *Yen-Phing FC*, ch. 45, p. 8b.

[h] For Kuang-Tung province see the +1687 *Hua HC*, ch. 3, p. 40a; +1731 *Chieh-Yang HC*, ch. 4, *wu-chhan*, p. 10a; 1884 *Chhao-Yang HC*, ch. 12, p. 6a. For Fukien province see the +1752 *Ting-Chou FC*, ch. 8, p. 5b.

[i] For Kuang-Tung province see the +1731 *Chieh-Yang HC*, ch. 4, *wu-chhan*, pp. 9b–10a. For Taiwan see the +1764 *Fêng-Shan HC*, p. 289.

[j] For Kuang-Tung province see the +1731 *Chieh-Yang HC*, ch. 4, *wu-chhan*, p. 12a.

[k] For Kuang-Tung province see the +1687 *Hua HC*, ch. 3, p. 40a which listed it by the local name, *lou yeh*[17].

[l] For instance in Kuang-Tung province the +1687 *Hua HC*, ch. 3, pp. 40b–41a listed *jen-mian tzu*[18] (*Dracontomelum Dao*, Merr. et Rolfe) and *i-mu-tzu*[19] as being candied. On Taiwan the *Chhih Chhien Pi Than* mentioned *yang*[20] (cited in *THSCL*, p. 59). The character which I have romanised *yang* here does not appear in dictionaries and the reading *yang* is only tentative.

[m] *KTHT*, p. 389.

[n] Martin, R. Montgomery (1), vol. 2, p. 122.

[1] 糖蜜 [2] 葛 [3] 糖葛 [4] 冬瓜 [5] 西瓜
[6] 橙 [7] 金橘 [8] 橘 [9] 柑 [10] 梅
[11] 香橼 [12] 落花生 [13] 荳蔻 [14] 糖果 [15] 瓜粕
[16] 西瓜糕 [17] 蔞葉 [18] 人面子 [19] 宜母子 [20] 柣

larly to India, the United States and South America. The total is about 10,000 boxes, valued at 50,000 dollars. A box is twenty-five catties.

In East Asia the Chinese were not alone in their taste for candied fruits. The +17th century empiricist, Ku Yen-Wu[1], in his *Thien Hsia Chün Kuo Li Ping Shu*[2] (The Strengths and Weaknesses of the Various Regions of the Empire) commented on the export of sugar products and candied fruit (*thang-phin kuo-phin*[3]) from Fukien to the Spanish in the Philippines along with silks from Chekiang and ceramics from Chiang-Hsi to pay for silver imports.[a] A French *religieuse* visiting Tongking[4] during the +18th century observed Vietnamese habitually consuming fruits preserved in sugar.[b]

Though most of our evidence derives from sugar-producing areas in south China, the consumption of candied fruit was not solely limited to that region. Quite to the contrary, studies of northern Chinese food in the modern period have found sugar-preserved green apricots and kumquats served as cold dishes, and candied fruits and brown-sugar syrup as ingredients included in 'eight precious rice'.[c]

(vii) *Feedstock for other handicraft industries*

In China we find instances of sugar utilised as a feedstock for such varied undertakings as apiculture and wine making. During the +17th century in Chao-Chhing prefecture, Kuang-Tung, bees feasted on boiled cane sugar over the winter months when flowers were out of bloom. Bees fed on the nectar of litchi and plum blossoms reputedly ripened the best honey, and cane sugar merely served as an interim measure.[d] Kanda Masao reported cane juice boiled in the first pan fed to pigs in Tzu-Chung[5] and Nei-Chiang[6] counties in Ssu-Chhuan.[e]

Some confusion exists about sugarcane wine and other alcoholic drinks deriving from sugar. In European possessions in tropical America, rum was the traditional alcoholic beverage prepared by the fermentation of sugarcane molasses or syrup.[f] It was distilled and concentration by volume varied from about 40 to 92.5 per cent.[g] Aldehydes and esters impart the distinctive rum flavour,

[a] *Thien Hsia Chün Kuo Li Ping Shu*, p. 1263.
[b] Richard (1), p. 335.
[c] Hsu & Hsu (1), p. 299.
[d] For Kuang-Tung province see +1640 *Chao-Chhing FC*, ch. 10, p. 80a and +1673 *Kao-Yao HC*, ch. 5, p. 44b.
[e] Kanda (1), p. 535.
[f] The great English navigator Captain James Cook tried his hand at making an alcoholic drink from sugarcane. Cook brewed beer from sugarcane that he procured from the inhabitants of the Hawiian islands in December +1778, but apart from the officers he could not induce any members of his crew to taste it, even by suspending their rum ration; see Cushing (1), pp. 18–19.
[g] There is much confusion in concentration specifications. Formerly it was registered at 1 per cent over or under proof, which was supposed to be the concentration at which the spirit would ignite. Proof in the USA is 50 per cent alcohol by volume and 57 per cent in the UK, see Blackburn (1), p. 336.

[1] 顧炎武 [2] 天下郡國利病書 [3] 糖品果品 [4] 東京
[5] 資中(縣) [6] 內江(縣)

which can be eliminated by appropriate distillation columns, yielding an azeotrope containing 96 per cent pure alcohol by volume. In the 20th century this is diluted and blended with gin, whisky and brandy concentrates to produce spirits indistinguishable from the genuine article by the inexperienced, and probably by connoisseurs as well.[a]

In Asia, sugarcane juice was fermented to produce sugarcane wine, and also distilled to make rum and arrack.[b] Unless texts render specific information there is no way of determining the type of alcohol prepared. Nevertheless, since the art of distilling wine was not known before the early Thang, as was shown in Volume 5, part 4,[c] sugarcane beverages prior to this date must have been unfortified wine. The Chinese visitor to Cambodia, Chou Ta-Kuan[1] (+1264? to 1346) in his *Chen-La Fêng Thu Chi*[2] (Description of Cambodia) of +1297 noticed sugarcane wine.[d] Wang Ta-Yüan[3] found the inhabitants of the Philippines 'boiling the sea to make salt, and brewing sugarcane syrup to make wine (*min chu hai shui wei yen niang chê chiang wei chiu*[4])' on his travels during the +1330s and +1340s.[e] Chinese sources do not abound in references to sugarcane wine, most probably because the Chinese living south of the Yangtse preferred rice wine. Yet, this did not prevent them from brewing it altogether, and indeed they did know of it from an early time. A Tun-Huang manuscript of the +9th to +10th century recorded: 'the molasses (*shui*[5]) that has been drained off [the sugar] is made into wine (*chiu*[6]).[f] This is probably the first written reference to making sugarcane wine from molasses in China. The *Thai Hai Shih Chha Lü*[7] (Records of a Circuit Censor in Taiwan) of +1736 mentioned that the syrup left over from the first, second and third claying was either boiled to make low grade sugar (*thang kao*[8] literally, sugar paste) or brewed to make wine (*niang chiu*[9]).[g] A 19th-century gazetteer for Lung-Yen sub-prefecture[10] in Fukien province noted the preparation of wine from sugar, and a European handbook for China of 1848 wrote, 'Rum is distilled from the sugar cane'.[h] In Chien-Yang county[11], Ssu-Chhuan, during the 1930s sugar boilers took juice, called scum (*phao-tzu*[12]) because it came from the first pan, to make a beverage they dubbed

[a] Blackburn (1), p. 337.

[b] Arrack (arak, araqi, rack) was a generic name for spirits distilled from such varying feedstocks as cane molasses, palm sap and grapes. In the Near East the name was applied to a fortified spirit flavoured with aniseed; see Yule and Burnell (1), pp. 36. For the possibility that the term originated in Central Asia, appearing in Chinese as *lo*[13], see Karlgren (5), p. 138.

[c] Vol. 5, pt 4, p. 158 and the argument on p. 132–58.

[d] *Chen-La Fêng Thu Chi*, p. 158.

[e] *Tao I Chih Lüeh*, pp. 23 and 89.

[f] Chi (*1*), p. 125.

[g] *THSCL*, p. 57.

[h] 1835 *Lung-Yen CC*, ch. 7, p. 5a. Anon (1), *A Brief Account of the Chinese Empire and Chinese Tartary*, p. 156.

[1] 周達觀 [2] 眞臘風土記 [3] 汪大淵 [4] 民煮海水爲鹽釀蔗漿爲酒
[5] 水 [6] 酒 [7] 臺海使槎錄 [8] 糖膏 [9] 釀酒
[10] 龍巖州 [11] 簡陽縣 [12] 泡子 [13] 酪

phao-tzu chiu[1] or foam wine for their own private consumption. It reputedly tasted similar to kaoliang wine[2].[a]

Builders often mixed sugar with cement for buildings and plaster for walls in Sumatra and on the Coromandel coast of India during the +18th century. William Marsden in his *The History of Sumatra* of +1783 remarked of palm sugar,[b]

> In this state it is called *jaggri* and besides its ordinary uses as sugar, it is mixed with *chunam* [lime] in making cement for buildings, and that exquisite plaster for walls which, on the coast of Coromandel, equals Parian marble in whiteness and polish.

The Dutch employed molasses as an ingredient in the adhesive substance for cementing the bricks in the construction of Fort Provintia on Taiwan in +1625.[c] This practice has not been documented for the Chinese mainland, but we do know that builders in 19th-century Siam mixed molasses from Chinese sugar mills with lime to make mortar.[d]

(viii) *The Mintz model and sugar as a food in China*

Chinese and European, mainly British, patterns of sugar consumption displayed a distinct qualitative difference in the 19th century. Mintz argued for two basic changes in the transformation from a luxury to a necessity, 'the first marking the popularization of sweetened tea and treacle, from about 1750 onward; and the second, the opening up of mass consumption, from about 1850 onward. Mass consumption after 1850 occurred as the price of sugar dropped sharply.'[e] The tables turned after 1850 when the poor became the biggest sucrose consumers, whereas prior to +1750 the wealthy had been the largest group. This change was generated by the ongoing development of the industrial economy and its shifting relationships with its overseas colonies. The main points of this thesis may be summarised as follows:

1 Plantations in the colonies provided low cost food substitutes, such as tobacco, tea, and sugar for the metropolitan labouring classes.
2 In the period +1750 to 1850 sugar (despite wide use, especially in combination with tea) did not make a significant calorific contribution to the English working-class diet. Nevertheless, sweetened tea increased workers' readiness to consume quantities of uninteresting complex carbohydrates, particularly breads. At the same time it saved time for working wives, and cut expenditures for cooking fuels. Tea and sugar played a fringe role to the core carbohydrates.

[a] Kanda (1), p. 535.
[b] Marsden (1), p. 187.
[c] Chuang Fang-Jung *et al.* (1), p. 12.
[d] Pallegoix (1), vol. 1, pp. 80–82.
[e] Mintz (1), pp. 147–9.

[1] 泡子酒 [2] 高粱酒

3 In the period 1850 to 1950, cheap sugar, the single most important addition to the British working-class diet during the 19th century, turned into an important source of calories; it became an ingredient in many conserved and prepared foods such as jams, cakes and ice-cream which were consumed in ever increasing quantities. By 1900 it contributed on average nearly one-sixth of the *per capita* caloric intake.

4 The conventional pattern of intrafamily consumption in Britain involved the monopolisation of costly protein foods such as meat by the adult male, while the wife and children ate proportionally larger quantities of sucrose to make up for deficiencies.

Mintz maintained that Europeans quickly adopted sugar because of the poverty of their diet; tea substituted for ale and milk, the sugar sweetener making it more attractive. How do these concepts compare with China?

Amorphous sugar, the principal product prior to the Thang, deliquesces and degenerates, so the transportation of large quantities of it was contingent on the adoption of clarification, boiling and crystallisation methods to attain sufficient purity for better keeping. As shown below, China only acquired this technology from India around the middle of the +7th century, probably prompted by imports of sugar products from Persia and India, during the Sui dynasty. In addition, storage procedures also had to be improved. Sugar makers devised elaborate methods for storage in jars, thousands of which were shipped from Fukien to mid-China during the Sung.[a] These factors strongly suggest that commodity production of sugar in the true sense, really only began during the late Thang and early Sung.

The phenomenon of increased sugar consumption during the Sung led Tai Kuo-Hui[1] to go so far as to claim, 'sugar became a necessity for urban dwellers between the Northern Sung and Yüan period'.[b] I, however, believe that this evaluation misrepresented the reality of the role of sugar in Chinese history. It is here that the Mintz model can delineate the differences in consumption patterns between China and the West. First, during the Sung, and indeed even in the present day, the Chinese have neither followed the Western custom of putting sugar in their tea, nor copied other European culinary habits involving saccharine substances to any great extent. Peasants, that is the vast majority of the Chinese population, have never consumed large quantities of cakes, biscuits, candied fruit, sugar preserves, jams and so on. It is significant that surveys of the diet of the working class in Peking undertaken from 1900 to the 1920s did not mention sugar.[c] The survey conducted by John Lossing Buck during the 1920s showed that the combined consumption of vegetables, sugar

[a] *Thieh-An Chi*, ch. 21, p. 4b.
[b] Tai (1), p. 31.
[c] Spence (1), pp. 267–71.

[1] 戴國煇

and fruit amounted to 0.7 per cent of the food energy of Chinese peasants, in comparison to 13.1 per cent for sugar and fruit alone in American families.[a] In other words, sugar never attained the status of a staple food and did not provide a large percentage of the daily calorie intake.[b] Between 1934 and 1938 the *per capita* consumption of centrifugal sugar in China averaged 1 kilo, a figure far lower than Japan and India where the average stood at 13.6 and 13.8 kilos respectively for centrifugal and non-centrifugal sugar;[c] sugar consumption in China was clearly low, even by non-European standards. Today the *per capita* consumption of sugar in China at 4.5 kilos is still considerably lower than the world average of 22 kilos, and way behind that of the advanced countries which exceeds 40 kilos.[d]

This is not to deny that the ordinary Chinese family ever ate sugar if given the opportunity. An early 20th-century Japanese student of contemporary Chinese customs and habits observed,[e]

In comparison with Japan relatively little confectionery is eaten, though there are exceptionally large numbers of different types of confectioneries, known by the general appellation of *chha shih*[1]. In Japanese homes it is a custom to entertain visitors with confectionery, but in China they are rarely offered though tea is always served. Furthermore, few children and adults have the vice of eating between meals. But on occasions, such as annual festivals, more confectionery is consumed than in Japan, and there are some that fall into the category of refreshments (*tien hsin*[2]). For instance, at the Feast of Lanterns (*yüan hsiao chieh*[3]) on the fifteenth day of the first lunar month, *yüan hsiao*[4] made from glutinous rice are eaten; during spring there are wisteria cakes (*thêng lo ping*[5]), in the fourth lunar month there are rose cakes (*mei-kuei ping*[6]), in the fifth lunar month five poison child pastries (*wu tu êrh po-po*[7]), while during summer soya bean cake (*lu-tou kao*[8]), glutinous rice crystal cold cake (*chiang-mi shui-ching liang kao*[9]) and at the mid-autumn festival held on the fifteenth day of the eighth lunar month there are moon cakes (*yüeh ping*[10]). There are many types of moon cakes, natural white (*tzu-lai pai*[11]), natural red (*tzu-lai-hung*[12]), turned hair moon cakes (*fan-mao yüeh ping*[13]), *chhi-su yüeh ping*[14] etc. Moon cakes are divided into two categories, meat and vegetable (*hun su*[15]), on the basis of their ingredients. Moon cakes with meat fillings are prepared by mixing sugar with lard or butter, and adding fruits such as hawthorns (*shan cha*[16]), longans, jujube (*tsao*[17]). Moon cakes with vegetable fillings are made with sesame oil (*hsiang yu*[18]), white and brown sugar; large ones presented as offerings to the full moon may

[a] Buck (1), pp. 363–4.

[b] However, it was adopted in times of famine. A gazetteer for Nan-Phing county in Fukien recorded sugar mixed with flour ground from common bracken (*chhüeh*[19]; *Pteris aquilina* L. R811) to make a famine food, see the 1872 *Nan Phing HC, wu pu*, ch. 1, p. 4b. Presumably the idea was to add extra calories to the flour to attain maximum effect.

[c] Tacke, Stepanov, Walker, Ali & Henning (1), pp. 209, 219 and 232. For comparison the *per capita* average in the United Kingdom during the same period was 48.4 kilos.

[d] Liu Shu-Khai (1), 159.

[e] Uchiyama (1), pp. 517–18 (tr. auct.); pp. 518–20 listed many more preserves and cakes.

[1] 茶食 [2] 點心 [3] 元宵節 [4] 元宵 [5] 藤蘿餅
[6] 玫瑰餅 [7] 五毒兒餑餑 [8] 菉豆糕 [9] 江米水晶涼糕 [10] 月餅
[11] 自來白 [12] 自來紅 [13] 翻毛月餅 [14] 起酥月餅 [15] 葷素
[16] 山渣 [17] 棗 [18] 香油 [19] 蕨

weigh over 100 *chin*[1] [c. 60 kilos]. Flower cakes (*hua kao*[2]) are eaten at the Chhung-Yang festival on the ninth day of the ninth lunar month, and hibiscus cakes (*fu-jung kao*[3]) and *sa-chhi-ma*[4,a] during winter.

Apart from these cakes which are baked in each season, confectioners in China mostly sell sponge cakes, biscuits and cheap sweets. The cheap sweets are exactly the same as those sold in Japan, the only difference being that the Chinese ones are generally larger. Sugar conserves constitute the most developed confectioneries in China, they are made from all types of fruit, melons and tubers, and are of particularly excellent flavour.

In short, ceremonies, festival days, particular periods in the year, special occasions such as feasts, provided excuses for the consumption of sugar and saccharine products. The crucial point is that such consumption has remained occasional rather than everyday until the present day.

Now to return to the original question of Sung consumption, we can safely say that it increased among more wealthy and affluent urban dwellers, but this did not constitute a general trend encompassing all sections of the population.[b] This same pattern prevailed even during the Ming and Chhing periods when overall sugar consumption rose. The *Kuang-Tung Hsin Yü* of +1700 wrote; 'For the most part people in Kuang-Tung [province] use much sugar in eating and drinking';[c] and a +17th-century gazetteer for the same province noted; 'People in Phan-Yü county make it [cane sugar] into powder and eat it in all seasons of the year. Families cannot do without it.'[d] Such references must be interpreted as referring to consumption by the wealthy and affluent sections of society and not by the peasantry. Despite a growing sugar market, and therefore increased consumption between the +16th to 20th centuries, sugar in China remained a semi-luxury, and very much the preserve of the wealthier classes. It functioned as a condiment, as medicine, in confectionery, in religious offerings, but never

[a] *Sa-chhi-ma* is thought to derive from a Manchu confectionery known as *sacima*. The great dictionary of the Manchu language, *Han I Araha Manju Gisun I Buleku Bithe*, 18 of +1708 recorded three types of *sacima*; *maishan halu i sacima* prepared with the flour of the nut of the medlar (*Chü Chhi*[5]; *Lysium chinense* Mill. R115); *mucu halu i sacima* which used the flour of ground grapes; and *šanggiyan halu i sacima* made with white flour. The same text described the latter as follows; '*šanggiyan halu i sacima*; Prepared by frying fine white flour in sesame oil, [adding] malt sugar and white sugar, dilute flavoured malt sugar and white sugar, and sprinkling washed sesame [over the top] (*šanggiyan halu i sacima; šanggiyan halu be malanggū nimenggi de carufi, uyan matan satan ucufi oboho jima malanggū sindafi weilembi*).'

This same passage is reproduced in the revised and enlarged version of this work with a preface dated +1772, *Han I Araha Nonggime Toktobuha Manju Gisun I Buleku Bithe*, ch. 27, p. 35b, but gave *thang chhan*[6] as the Chinese translation of *sacima*. The meaning of the text has not been altered, though as can be seen from the following transcription there has been a change in the orthography of some words; '*Sacima: sanyan halu be malanggū menggi de carufi uyan matan satan ucufi oboho malanggū sindafi weilembi*.'

For an account of *sacima* see Ishibashi (*1*).

[b] It is significant that Uchiyama (Uchiyama (*1*), pp. 431–2), who wrote of the early 20th century when imports of foreign sugar into China were increasing, mentioned no use of confectionery for families on the lower end of the social scale (the vast majority of the population), and reported that it was rarely eaten in families at the middle level, but regularly by those of the upper classes.

[c] *KTHY*, p. 389.

[d] +1686 *Phan-Yü HC*, ch. 15, p. 19a.

[1] 斤 [2] 花糕 [3] 芙蓉糕 [4] 薩齊馬 [5] 枸機 [6] 糖霜

as a staple part of the daily diet providing one sixth of the daily calorific intake of the average Chinese peasant as with the worker in Britain of 1900. The different consumption patterns in China and the West reflect the contrasting natures of their economies and societies, agricultural and industrial respectively. When viewed in comparison with Europe, the low level of consumption in China placed limits on the expansion of production, and restricted the need for the indigenous development of mass production in factories.

Even today, the Chinese, though striving to industrialise, still do not consume sugar in large quantities like their Western counterparts. This situation persists despite the great diversification of the five principal uses of sugar since the Sung dynasty at least. The explanation probably lies in the great variety of edible foods available to the Chinese, especially honey and a wide range of vegetables and fruits that could act as substitutes for sugar sweeteners.[a] The historical pattern of sugar consumption in China indicates that it was not just the differentiation of the five principal uses and their embedment in modern life that caused sugar to become a food of calorific importance. Rather one is tempted to suggest that more than anything else, it was the poverty of the traditional European diet, and its inability to cope with changes in eating patterns caused by the Industrial Revolution, that promoted the use of sugar as a staple food.

(3) An Outline of the Development of Sugar Production in China

The manufacture of sugar products was one of the first extensive agro-industrial operations in the world apart from textiles. In India the armies of the renowned Gupta ruler Harsha (+606 to +647) marched with supplies of cane syrup, and in +627 when the Byzantine emperor Heraclius captured Dasteragah in Persia he obtained large quantities of sugar.[b] The *Arthasātra* of roughly −100 listed ten *palas* of molasses (*kshāra*) among the rations for an elephant.[c] Small sugar-processing plants appeared in the Jordan valley prior to +1,000 spreading to larger operations in Egypt, Cyprus, Sicily and Spain by the +13th century. In China, large processing plants with edge-runner mills emerged during the Sung, probably in response to the contemporary increase in commerce. During the European Renaissance, and for the succeeding two centuries, sugar manufacture constituted one of the largest pre-modern industrial operations in the world. Some of the first 'factories' processed sugarcane; in fact Ladislao Reti has pointed out that the Turriano manuscript of c. +1560 contains the first designs for a centrally powered automated factory, one of which was a sugar mill.[d] From the late +16th century Chinese methods of sugar manufacture travelled

[a] For the array of vegetables and fruits available to the Chinese from ancient times see Vol. 6, pt 2, pp. 539–50.
[b] Gopal (1), p. 58; Deerr (1), p. 69.
[c] Shamastry (1), p. 155.
[d] Reti (12).

to the Philippines, Vietnam, Java and other South-East Asian states, the Ryūkyū Islands and Japan.

Before examining the technological history of sugar production in China we must have background knowledge of the economic aspects of its history. Here I provide an outline history of Chinese sugar in the light of the consumption patterns already defined. I believe this to be a suitable context for understanding the way in which different generic technologies were adapted to sugar production in China.

(i) *Pre-Sung period*

As demonstrated below, the ethnic peoples of south China and Vietnam boiled amorphous sugar, *shih-mi*, from the −2nd century. Such sugar was not produced for trade with central and north China, and only found its way to the Chinese court as an article of tribute. The Han Chinese learnt about the sugarcane plant and the method of making *shih-mi* from the ethnic peoples after settling in south China, which then included the area covering present-day North Vietnam. Pharmacopoeias mentioned various types of sugars from the +6th century onwards, but being imported medicines their consumption was confined to the higher echelons of society. The dynastic histories recorded the import of sugar from countries lying to the west of China from the Sui dynasty. The mid-7th-century technological mission to India, which we examine in detail below, introduced the method of making *sha thang* or beaten sugar, and muscovado or drained sugar (*shih-mi*). Clarification of sugarcane juice with milk, a most effective method, also arrived in China about the same time. Despite the introduction of these sugar-making technologies in the +7th century, social and economic conditions did not allow the development of a commodity market for sugar, as with other agricultural products, for the following reasons. First, it was not until the decentralisation of political power during the late Thang that strict State control over commerce, merchants, the rural population and the currency ended.[a] Second, a lack of conditions for ensuring a constant supply of sugarcane for sugar making on a commercial basis prevailed. Ethnic people, using agricultural techniques unsuited to the commercial production of sugarcane, far outnumbered Chinese settlers in south China. The assimilation and training of ethnic peoples in the Chinese arts of cultivation only reached effective levels by the Sung. Third, the contemporary tendency to keep technological methods secret hampered the fast spread of the new sugar-making methods.

(ii) *The beginning of commodity production; Sung and Yüan*

The rise of large urban markets in the Sung encouraged sugar production by Han Chinese immigrants living south of the Yangtse, and quickly turned sugar

[a] Twitchett (11), pp. 22–31.

into a commodity. Both Khai-Fêng and Lin-An, the capitals of the Northern and Southern Sung respectively, enjoyed high acclaim for the sugar products vended on their streets. For instance, the *Tung Ching Mêng Hua Lu* which depicted conditions in Khai-Fêng during the early +12th century, listed Ssu-Chhuanese milk sugar (*Ssu-Chuan ju-thang*[1]), lion-shaped sugar (*shih-tzu thang*[2]), and a variety of other products bearing exotic sounding names that were processed with sugar, such as chicken's head *sha thang* (*chi-thou jang sha thang*[3]) and fragrant candied sugar (*hsiang thang kuo-tzu*[4]).[a] The *Tu Chhêng Chi Shêng*, which described Lin-An, later known as Hangchow, during the early +13th century recorded a similarly abundant amount of sugar consumed. Street vendors sold an array of sugar and candied fruits, and there was even a government organisation called the *mi chien chü*[5] or honey-boiling department which purveyed fruits boiled in sugar and honey to government officials and those of high social standing.[b]

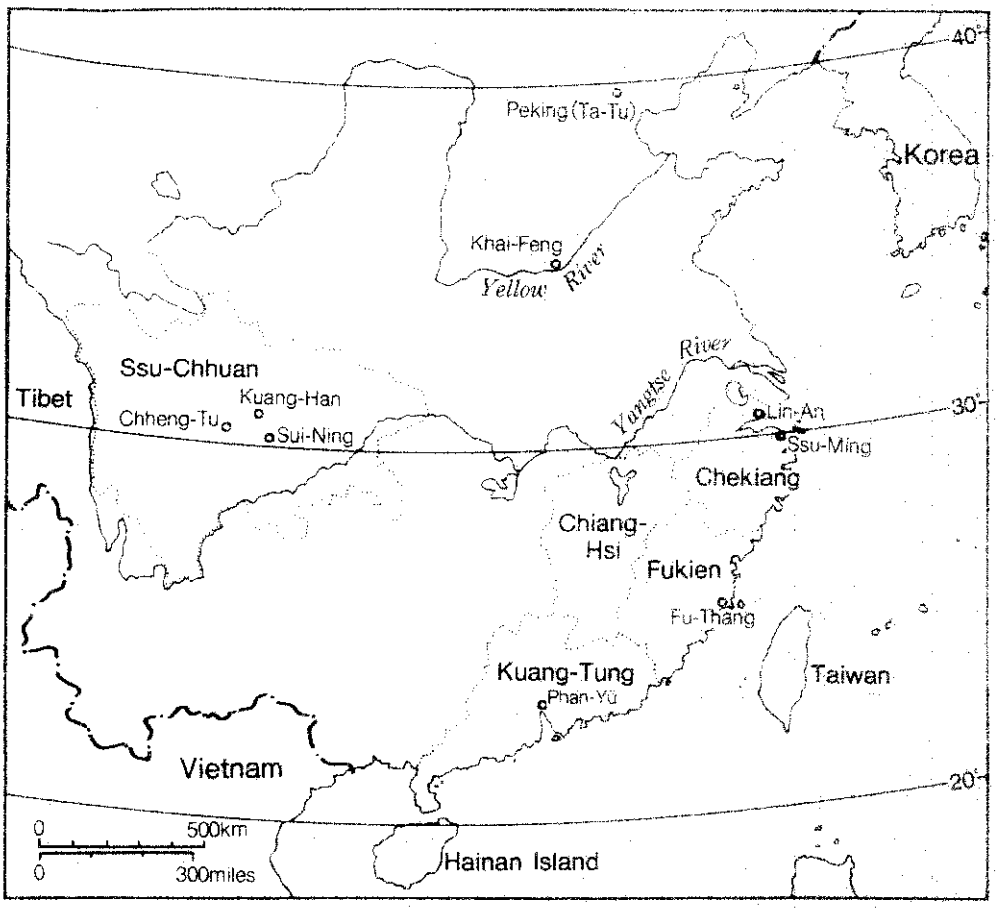
The late Thang and Sung periods marked the commencement of the commercial production of both sugarcane and sugar. The *Thang Shuang Phu* of c. +1154 described the contemporary situation in the following terms:[c]

> Sugar candy (*thang shuang*[6]), also called ice sugar (*thang ping*[7]), is produced in Fu-Thang[8] [Fukien], Ssu-Ming[9] [Chekiang], Phan-Yü[10] [Kuang-Tung], Kuang-Han[11] and Sui-Ning[12] [both in Ssu-Chhuan. [The sugar candy manufactured] in Sui-Ning alone is the best, while [the crystals of that] made in the [other] four counties are very small and brittle, their colour light, and their flavour thin. [Such products] are only comparable to the lowest [grade sugar candy] from Sui-Ning.
>
> Things attain rarity when they are scarce and difficult [to obtain]. The world esteems and values hawthorns [*cha*[13]; *Crataegus cuneata* Sieb. et Zucc. R422], pears [*li*[14]: *Pyrus kikuchi* Hort.], coolie oranges [*chheng*[15]; *Citrus aurantium* L. R343], citrus (*kan*[16]),[d] lychees [*li-chih*[17]; *Litchi chinensis* Sonn R300] and strawberries [*yang-mei*[18]; *Myrica rubra* Sieb. et Zucc. R621] because they are not produced in all the four quarters. Sugarcane is not regarded as an unusual thing because it is grows excellently where ever found. Despite the great size of China, only the five counties [listed above] can condense (*chieh*[19]) [the juice of] sugarcane into sugar candy, and that produced in Sui-Ning is singularly beautiful. The four barbarians, the I[20], Ti[21], Jung[22], and Man[23] who live outside the pale of Chinese civilisation all have superb sugarcane, but I have never heard of [them making] sugar candy. This is a principle of things that cannot be explained.

Contemporary commercial sugar production was concentrated in five specific locations in Chekiang, Fukien and Kuang-Tung and Ssu-Chhuan. This concen-

[a] *Tung Ching Mêng Hua Lu*, p. 17.
[b] *Tu Chhêng Chi Shêng*, pp. 91 and 94. For other sources concerning sugar consumption in urban areas during the Sung see Tai (*1*), pp. 31–4.
[c] *TSP*, p. 1a.
[d] Vol. 6, pt 1, p. 369, fn. b.

[1] 四川乳糖 [2] 獅子糖 [3] 鷄頭稜沙糖 [4] 香糖果子 [5] 蜜煎局
[6] 糖霜 [7] 糖冰 [8] 福唐 [9] 四明 [10] 番禺
[11] 廣漢 [12] 遂寧 [13] 查 [14] 梨 [15] 橙
[16] 柑 [17] 荔枝 [18] 楊梅 [19] 結 [20] 夷
[21] 狄 [22] 戎 [23] 蠻



Map 1. Main commercial sugar-producing places in the Sung and Yüan periods (present-day provincial boundaries).

tration probably arose from a monopoly of crystallisation technology by people in these areas manufacturing for inter-regional urban markets, combined with favourable precipitation levels for sugarcane cultivation. We can gain some idea of the scale of operations in Ssu-Chhuan from the description of the organisation of production given in this same source:[a]

Umbrella mountain (*san shan*[1]) located in Hsiao-Hsi county[2], twenty *li*[3] east of the Fu river[4], stands out elegant and superb. Forty per cent of the agricultural land around the mountain is cane land, while thirty per cent of the households engage in making sugar candy . . .

Sugar candy is made at the following places; at Li-Fo Pa[5] beneath [Umbrella] mountain, at Kan-Than Pa[6] five *li* from the mountain, Shi-Hsi Pa[7] ten *li* away, and [in the

[a] *TSP*, pp. 3a–3b.

[1] 繖山 [2] 小溪縣 [3] 里 [4] 涪江 [5] 禮佛壩
[6] 乾灘壩 [7] 石溪壩

area] west of the Fu river facing Umbrella mountain known as Fêng-Thai market town[1]. There are roughly close to three hundred odd families [producing sugar candy]. Families who produce more make several tens of jars while those producing less make one or two jars.

There are also close to one hundred families who only produce middle and low grade sugar candy at Chang village[2] and Hsiang-Khou[3] left of Umbrella mountain, at Nuan-Chhih[4] and Wu village[5] behind the mountain, and west of the Fu river at places known as Fa-Pao Yüan[6] and Ma-An mountain[7] which face Umbrella mountain ...

Furthermore, despite having many cane fields, [the growers] in the vicinity of Umbrella mountain at places, known as, Pai-Shui market town[8] and Thu bridge[9], lack the ability to make sugar candy. Every year they extract heavy syrup [not drained molasses] by pressing (*ya thang-shui*[10]), and sell it to the various [sugar candy making] households in front of the mountain.

Sugar candy production within Sui-Ning took place around Umbrella mountain, and did not occur throughout the whole county. A core group of three hundred households with the ability to make high-grade sugar candy, and a fringe group of another hundred households making medium and low-grade sugars, constituted the main body of producers. In addition, an outer fringe group, unable to produce sugar candy themselves, simply sold their sugarcane juice to the sugar-candy-making households. The reasons for these households not engaging in the production of the more valuable sugar were probably economic as much as technological, since it would have required more capital to cover losses incurred by the vagaries of the weather. As will be explained later, the Ssu-Chhuanese technology solely depended on the winter cold to supersaturate the sugar solution for inducing crystal growth. In such a situation a sudden bout of warm winter weather could cause havoc and ruin by dissolving all the sugar crystals back to heavy syrup.

This same passage from the *Thang Shuang Phu* also demonstrated that even in a major production centre, sugarcane cultivation only occupied 40 per cent of the agricultural land. For Sung times this represented a large percentage of land to be devoted to a single commercial crop in a single area. A multitude of family units undertook production on relatively small plots of land, rather than on big plantations or estates with large numbers of slaves or other forms of subordinate labour at their command.

During the Yüan dynasty the great Venetian traveller Marco Polo marvelled at the amount of sugar produced in China. Concerning the revenue of Hang-chow he related:[a]

I tell you that sugar, which pays three and a third per cent, grows and is made in this city and its dependencies, which is one of the nine parts of the province of Mangi, and it is also made in the other eight parts of the said province everywhere, and so it is made in this province in very great quantity and more than double that which is made in all

[a] Moule & Pelliot (1), p. 341

[1] 鳳臺鎮 [2] 張村 [3] 巷口 [4] 湍池 [5] 吳村
[6] 法寶院 [7] 馬鞍山 [8] 白水鎮 [9] 土橋 [10] 壓糖水

the rest of the world; many people say it in truth and this is again a very great source of revenue.

There may be some exaggeration in this statement, but Marco Polo was by no means the only contemporary foreigner to praise the excellence of Chinese sugar. Abu'l Abbas Ahmad Shinab al-Din al-'Umari (d. +1338), in his *Masalik al-Absar fi Mamalik al-Amsar* (Ways of the Eyes to Survey the Provinces of the Great States) spoke of the great skill of Chinese artisans in making sugar candy.[a] A work sponsored by the Yüan court, the *Nung Sang Chi Yao*[1] (Fundamentals of Agriculture and Sericulture) of +1273, documented sugarcane agriculture and sugar-making techniques, which itself provides some indication of the increased importance of this crop. In fact the Yüan established a Sugar Bureau (*Sha-Thang Chü*[2]) in + 1276, the same year in which the Mongols pacified the Chiang-Nan region. According to the *Yüan Shih*[3] (History of the Yüan Dynasty) it managed the boiling and manufacture of *sha-thang*[4] and honey, as well as the tribute of fruit and trees presented from various parts of the Empire.[b] The commodity production of sugar which began during the Sung continued throughout the Yüan dynasty.

During the Sung, specialist areas in south China exported sugar to a number of places in South-East Asia, such as Vietnam, Cambodia and Sri Vijaya and the northern parts of the Malay Peninsula.[c] We may surmise that they did not export amorphous sugars, which in any case had been made in South-East Asia from the early centuries of the present civil era at least, but specialist sugars such as sugar candy and *sha-thang*. These Chinese sugars would have been exported from Fu-Thang, in Fukien, Ssu-Ming in Chekiang and Phan-Yü near Kuang-Chou all of which manufactured sugar candy during the Sung.[d] From the Sung onwards sugar candy became increasingly popular as a commodity. We find it sold on the inter-regional market at Ssu-Ming in Chekiang during the +1330s.[e] A Japanese source, the *Gonijōshi Tsūtsūki*[5], recorded sugar imported from Sung China being given as gifts to officials at the Heian[6] court at Kyoto[7] in +1091.[f]

One of the factors limiting the expansion of the commodity production of sugar was the nature of sugar-making technology. The crystallisation of sugar candy in cold areas depended on the weather, and as Wang Cho warned in his *Thang Shuang Phu* warm winters could ruin entire jars. Such conditions clearly

[a] Schefer (2), p. 20.
[b] *Yüan Shih*, ch. 87, p. 2204. Tai Kuo-Hui (Tai (1), pp. 35–6) speculated that the Sugar Bureau may have been modelled after the *mi chien chü* of the Southern Sung.
[c] Wheatley (1), p. 86.
[d] *TSP*, p. 1a.
[e] +1342 *Ssu-Ming Hsü Chih*, ch. 5, p. 2b, p. 5892.
[f] Quoted in Tai (1), p. 34.

[1] 農桑輯要 [2] 沙糖局 [3] 元史 [4] 沙糖
[5] 後二條師通通記 [6] 平安 [7] 京都

limited the amounts of sugar candy that could be annually produced, and the market must by necessity have been small and the sugar prices high. The expansion of the sugar market had to await the appearance of more reliable crystallisation techniques during the Ming.

(iii) *The golden age of Chinese sugar: expansion of sugar production from the mid-Ming to the late Chhing*

The Ming and Chhing periods truly heralded the golden age of sugar production in Chinese history. The amount of sugar marketed reached unprecedented levels, but without the development of a slave-based plantation economy as in tropical America. In China sugarcane cultivation and sugar manufacture was always undertaken by tenant and owner–cultivator peasants working small plots of land. Sugarcane continually had to compete with rice and other subsistence and commercial crops, and never turned into a monoculture. Chinese and Japanese historians have devoted considerable effort to debating the nature of landlord–tenant relations, but whatever it was, it was not slave labour in the tropical American sense.[a] In fact, during the late +18th century Henry Botham, an ex-East India planter with experience in Java and Sumatra as well as the West Indies, expounded the superior efficiency of Chinese 'free' labour over slave labour on sugar plantations before a select committee in the House of Commons. In China sugar production never carried the opprobrium of plantation slavery, but remained the domain of the small-scale peasant.

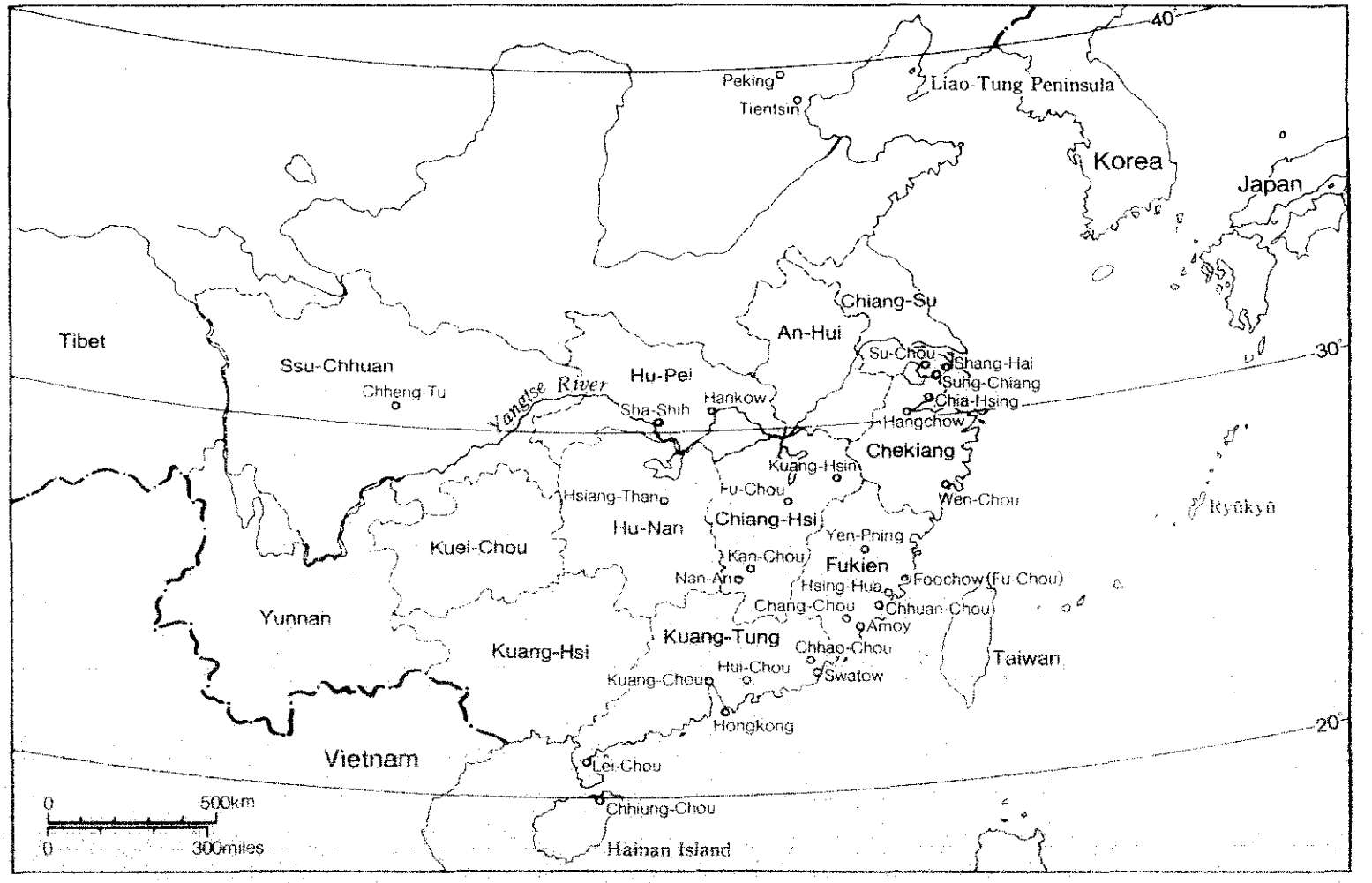
Chu Yüan-Chang[1], the first Ming Emperor, ever conscious of his peasant origins, introduced policies for resettlement and land reclamation after the turmoil of the late Yüan. Early Ming policy aimed to foster an economy founded on the idea of a small land-owner using his own family labour. In principle it relied on the 'self-sufficient peasant who combined agriculture with household industry and who could provide for the fiscal needs of the state:[b] The Ming State implemented the *li-chia*[2] system to maintain control over rural areas and collect tax. This system functioned by dividing the population into groups of 110-household units; each acting as the medium for collecting taxes, ensuring mutual security and generally maintaining control over rural areas.[c] Allocated on an annual rotating basis, each household served once every ten years in sub-groups of eleven. Such a system must have restricted the growth of the commodity production of sugar as with other agricultural crops, and indeed we do not hear

[a] For translations of Japanese studies on landlord–tenant relations see articles in Grove & Daniels (1). Oyama Masaaki argued that until the late Ming early Qing production in China was based on slave labour, but his assertion is not generally accepted by Japanese historians (see Oyama (1)). Though scholars claim varying degrees of bondage for tenants, I know of no case of slaves producing sugar in China.

[b] Tsurumi (1), p. 250.

[c] For a detailed study of the *li-chia* system as a State method for rural control see Tsurumi (1).

[1] 朱元璋 [2] 里甲



Map 2. Main commercial sugar-producing regions during the Ming and Chhing periods; selected prefectures and towns (present-day provincial boundaries).

of further developments until the +16th century after which the *li-chia*[1] system began to collapse. This breakdown left immediate producers freer to engage in production for the market, the rewards of which must have appeared increasingly more attractive, as the money economy expanded with the inflow of silver from Japan, and the American continent via the Spanish in the Philippines.[a] All of these factors, in addition to the adoption of new extraction and clarification technologies after the +15th and +16th centuries combined to encourage widespread production of sugar in Fukien province.

Though we possess no data for other provinces, sugar first appeared as an article in the tribute presentation quota (*shang kung wu liao*[2]) for Fukien during the Yung-Lo[3] reign period (+1403 to +1424).[b] During the Ming dynasty, the Imperial court and various government offices requisitioned articles required for their use through the regular *li-chia* labour services imposed on the general populace. The State chose to collect sugar from Fukien due to its long history as a sugar-making region. There are numerous examples of white sugar included amongst the tribute items furnished to the central government, and *sui-pan*[4] or annual contributions to the local government collected through the *li-chia* system. Sugar requisitioned in this way was divided into two grades; black and white, and as can be seen from Table 8 by contemporary world production standards significant quantities were made just to meet tax demands. Note that Table 8 only lists the amounts of sugar paid in kind, and does not include the numerous cases of commutation to silver.[c] For instance, apart from Fu-Chou[5] all the prefectures furnished over one tonne of white sugar *per annum*, while Chang-Chou prefecture[6], a major sugar-producing area until the present day, submitted roughly 3.5 tonnes, and even a single county Lung-Hsi[7] within its jurisdiction presented over 1.5 tonnes annually during the early +16th century. After the mid-Ming the procurement of articles of tribute became a heavy burden for the current-year *li-chia*, and the general break-down of the whole system explains why sugar disappeared from the tribute lists by the +17th century.

Yet the collapse of the *li-chia* system did not halt sugar production. Quite to

[a] For the inflow of foreign silver into China and the effects on the domestic economy, see Atwell (1).

[b] For example the +1596 gazetteer for Fu-Chou prefecture, the administrative capital of Fukien, specifically stated that the furnishing of red and white sugar (*hung pai thang*[8]) as tribute commenced after the Yung-Lo period, see the +1596 *Fu-Chou FC*, ch. 7, p. 8b. The +1531 gazetteer for Tê-Hua county in Fukien province listed 350 *chin* of white sugar as a new item of tribute introduced during the Yung-Lo reign period, but did not list it for the earlier Hung-Wu[9] period (+1368 to +1398). This same gazetteer also listed 468 *chin* of white sugar (*pai-sha-thang*[10]) and 204 *chin* of black sugar (*hei sha-thang*[11]) as products to be delivered to the State as annual contributions or *sui-pan*, see the +1531 *Tê-Hua HC*, ch. 4, p. 8b. Other evidence can be found in the +1612 *Chhüan-Chou FC*, ch. 7, p. 1b which recorded the submission of white sugar, sugar candy and black sugar (*sha li pieh*[12]) to the State as tribute from the Yung-Lo period.

[c] For examples of the commutation of white and black sugar contributions to silver see +1530 *Yu-Hsi HC*, ch. 3, p. 32a.

[1] 里甲 [2] 上供物料 [3] 永樂 [4] 歲辦 [5] 福州府
[6] 漳州府 [7] 龍溪縣 [8] 紅白糖 [9] 洪武 [10] 白沙糖
[11] 黑沙糖 [12] 沙哩唎

Table 8. *Amount of sugar tribute submitted in kind in Fukien during the +15th and +16th centuries according to prefectures and counties*[a]

Area	Date	White Sugar		Black Sugar	
		Chin[b]	Kilos	Chin	Kilos
Yung-Chun Sub-Prefecture[1]					
Tê-Hua county[2]	+1403–1424[c]	350	210	—	—
Tê-Hua county[2]	+1531[d]	468	280	204	122
Chang-Chou Prefecture[3]					
Chang-Chou Pref.[3]	+1513[e]	5,702	3,421	2,500	1,500
Chang-Chou Pref.[3]	+1522–1566[f]	4,570	2,747	2,000	1,200
Lung-Hsi county[4]	+1513	2,627	1,576	1,152	691
Chang-Phu county[5]	+1513	1,314	788	575	345
Lung-Yen county[6]	+1513	500	300	221	132
Lung-Yen county[6]	+1558[g]	572	343	250	150
Chhang-Thai county[7]	+1513	207	124	91	54
Nan-Ching county[8]	+1513	485	291	210	126
Nan-Ching county[8]	+1522–1566[h]	577	346	—	—
Chang-Phing county[9]	+1513	570	342	251	150
Hsing-Hua Prefecture[10]					
Hsing-Hua prefecture[10]	+1575[i]	2,588	1,130	1,130	678
Fu-Chou Prefecture[11]					
Chhang-Lo county[12]	+1503[j]	1,121	672	656	393
Fu-Ning Chou[13]	+1593[k]	976	585	441	217
Ning-Tê county[14]	+1538[l]	599	359	265	159
Ning-Tê county[14]	+1591[m]	599	359	265	159
Lo-Chhuan[15]	+1545[n]	267	160	94	56
Yen-Phing Prefecture[16]					
Sha county[17]	+1545[o]	1,768	1,060	621	372
Ting-Chou Prefecture[18]					
Ting-Chou Prefecture[18]	+1637[p]	5,138	3,082	1,803[q]	1,081
Chhang-Ting county[19]	+1637	851	510	199	119
Ning-Hua county[20]	+1637	851	510	199	119
Chhing-Liu county[21]	+1637	851	510	299	179
Kuei-Hua county[22]	+1516[r]	750	450	363[s]	217
Lien-Chheng county[23]	+1637	534	320	187	112
Shang-Hang county[24]	+1637	667	400	234	140
Wu-Phing county[25]	+1637	317	190	111	66
Yung-Ting county[26]	+1637	317	190	111	66
Shao-Wu Prefecture[27]					
Shao-Wu prefecture[27]	+1623[t]	4,384	2,630	1,531[u]	678
Shao-Wu county[28]	+1623	2,269	1,361	796	477
Kuang-Tse county[29]	+1623	734	440	258	154
Thai-Ning county[30]	+1623	694	416	243	145
Chien-Ning county[31]	+1623	667	400	234	140

[a] For the purpose of clarity this table does not include the figures for the commutation of the sugar tax into silver though this information is provided in many cases.

[b] During the Ming dynasty one *chin* was equivalent to 600 grammes.

[c] +1531 *Tê-Hua HC*, ch. 4, p. 8b.

the contrary, the expansion of the money economy and commercial agriculture raised production levels to new heights, and during the early +17th century Fukien and Kuang-Tung indisputably emerged as the two major cane-sugar-producing regions of the Empire, honours which they still retain today. Sung Ying-Hsing in his *Thien Kung Khai Wu* of +1637 estimated that together they manufactured 90 per cent of the cane sugar output of China, while all other provinces only provided the remaining 10 per cent.[a] There was a definite historical order of development here. Fukien continued to enjoy its position as a major sugar producer after the +16th century, but as we shall presently see sugar production expanded in Kuang-Tung only after the transfer of new tech-

[a] *TKKW*, p. 162.

Notes to Table 8 (*cont.*)

[d] +1531 *Tê-Hua HC*, ch. 4, p. 10b.

[c] +1513 *Ta Ming Chang-Chou FC*, ch. 8, pp. 26b–32b. All the +1513 references below for Chang-Chou prefecture are to this gazetteer. The same total figures for Chang-Chou prefecture as a whole are given in the 1628 *Chang-Chou FC*, ch. 8, p. 38a.

[f] +1628 *Chang-Chou FC*, ch. 8, p. 38b.

[g] +1558 *Lung-Yan HC*, ch. 2, p. 50a.

[h] +1599 *Nan-Ching HC*, ch. 4, p. 4a.

[i] +1575 *Hsing-Hua FC, Thien Fu Chih*, p. 40a.

[j] +1503 *Chhang-Lo HC*, ch. 2, p. 42a.

[k] +1593 *Fu-Ning CC*, ch. 4, p. 21b.

[l] +1538 *Ning-Tê HC*, ch. 1, pp. 17b–18a.

[m] +1591 *Ning-Tê HC*, ch. 2, p. 39a.

[n] +1545 *Lo-Chhuan Chih* ch. 2, p. 56b.

[o] +1545 *Sha HC*, ch. 4, p. 1a.

[p] +1637 *Ting-Chou FC*, ch. 9, p. 10a. All the +1637 references below for Ting-Chou prefecture are to this gazetteer.

[q] The total of the figures for the eight counties given in the +1637 *Ting-Chou FC* only comes to 1,603 *chin*. Tai, on the basis of the rate for Chhing-Liu county, 851 *chin* of white sugar to 299 *chin* of black sugar, speculated that the 199 *chin* for Chhang-Ting and Ning-Hua counties were mistakes for 299 chin (Tai (*1*), p. 50). However, the +1516 *Kuei-Hua HC*, ch. 4, *Thu-Kung* gave 363 *chin* of black sugar for Kuei-Hua county instead of the 263 *chin* in the +1637 gazetteer, and supposing that all the other figures in the latter gazetteer were correct this would give a total of 1,703 *chin*.

[r] +1516 *Kuei-Hua HC*, ch. 4, *Thu-Kung*. Sugar was not listed as an article of local tribute (*thu-kung*) in the +1614 *Kuei-Hua HC*.

[s] The +1637 *Ting-Chou FC*, ch. 9, p. 10a recorded 263 *chin* but I give the +1516 *Kuei-Hua HC* as it is earlier and therefore more accurate.

[t] +1623 *Shao-Wu FC*, ch. 30, pp. 8b–10b. All the +1623 references below for Shao-Wu prefecture are to this gazetteer.

[u] Tai gave a total of 1,131 *chin* for black sugar and says that the figures for the whole prefecture do not match the sum total of the four counties (Tai (*1*), p. 50). However, the original has the figure 1,531 *chin* which is the sum total of the four counties and we can only assume that Tai made a mistake when handcopying from the original.

[1] 永春州 [2] 德化縣 [3] 漳州府 [4] 龍溪縣 [5] 漳浦縣
[6] 龍巖縣 [7] 長泰縣 [8] 南靖縣 [9] 漳平縣 [10] 興化府
[11] 福州府 [12] 長樂縣 [13] 福寧州 [14] 寧德縣 [15] 羅川
[16] 延平府 [17] 沙縣 [18] 汀州府 [19] 長汀縣 [20] 寧化縣
[21] 清流縣 [22] 歸化縣 [23] 連城縣 [24] 上杭縣 [25] 武平縣
[26] 永定縣 [27] 邵武府 [28] 邵武縣 [29] 光澤縣 [30] 泰寧縣
[31] 建寧縣

nology by Fukienese immigrants during the +17th century. The supreme position of Fukien as manufacturer of handicraft goods during the latter half of the +16th century can be ascertained from the following account by Wang Shih-Mao[1] (+1536 to +1588) in his *Min Pu Su*[2], preface dated +1586:[a]

There is much sugarcane grown on the islands in the rivers. Although the local people carry it to the city markets to sell, they do not make much money from it (*pho pu teng hsiu*[3]) ...

Everyday endless streams of fine silk from Fu-Chou, gauze and pongee from Chang-Chou, indigo from Chhüan-Chou, steel from Fu-Chou and Yen-Phing, bitterpeel tangerines (*chü*[4]) [*C. noblis* Lour. (Ch) R347] from Fu-Chou and Chang-Chou, lichees from Fu-Chou and Hsing-Hua, sugar from Chhüan-Chou and Chang-Chou, paper from Shun-Chang are carried over into Chiang-Su and Chekiang provinces (*Wu Yüeh*[5]) through the Fên-Shui pass[6] [an outlet from Fukien province to Yen-Shan county[7] in Chiang-Hsi province] and the small pass in Phu-Cheng[8] [county which borders on Chekiang]. Countless amounts [of these commodities] are shipped away across the great ocean and they all benefit the Empire. The only article for which [Fukien] depends on other provinces is Hu-Chou silk.

Here we see the specialisation of agro-industrial production within Fukien province itself. Peasants around Fu-Chou actively engaged in the cultivation of sugarcane for sale as a fruit in the urban areas, while sugar was mainly made in Chhüan-Chou[9] and Chang-Chou[10] prefectures, the main producers for the inter-regional trade. Market forces now encouraged the specialisation of sugar production in these two seaboard prefectures, which enjoyed a climate suitable for sugarcane cultivation, whereas earlier the State for fiscal reasons had, through the *li-chia* system, imposed sugar production on all prefectures regardless of terrain and local climatic differences.

Sources such as the *Min Shu*[11] of +1631 attested to the growing importance of Fukienese sugar in the intra-Empire trade network, 'The local people grind the juice [from sugarcane] to boil into sugar. [They] sail by sea to sell [it] in Chiang-Nan and Chekiang.'[b] Increased consumption of sugar on the Empire-wide market, especially in the wealthy lower Yangtse provinces, also encouraged the expansion of sugar production in Fukien. An example of contemporary sugar consumption can be seen in the case of Hsing-Hua county[12], Yang-Chou prefecture[13] in Chiang-Su province during the first half of the +16th century. A local gazetteer recorded the consumption of white sugar (*pai-thang*[14]) and sugared dates, and since it did not list sugarcane as a local product, the white sugar must have been imported.[c]

[a] *Min Pu Su*, pp. 13 and 47.
[b] *MS*, ch. 150, p. 33a.
[c] +1591 *Hsing-Hua Hsien Hsin Chih*, ch. 2, p. 19b.

[1] 王世懋 [2] 閩部疏 [3] 頗不登蔗 [4] 橘 [5] 吳越
[6] 分水嶺 [7] 鉛山縣 [8] 浦城 [9] 泉州府 [10] 漳州府
[11] 閩書 [12] 興化縣 [13] 揚州府 [14] 白糖

Fukien and Kuang-Tung exported sugar overseas as well as shipping it to other parts of the Empire. Chhü Ta-Chün (+1630 to +1696) in his *Kuang-Tung Hsin Yü* reported that in Kuang-Tung province during the late +17th century local people reserved most of their whitest sugar, named ocean sugar (*yang-thang*[1]), for export.[a]

After [crushing, sugarcane juice] is boiled (*chu liên*[2]) to make sugar (*i*[3]). The turbid (*cho*[4] [i.e. contains many impurities]) and black sugar is called black piece sugar (*hei phien-thang*[5]). Clear (*chhing*[6]) and yellow sugar is known as yellow piece sugar (*huang phien-thang*[7]), single clear (*i-chhing*[8]) is termed red sugar (*chhih sha-thang*[9]), double clear (*shuang-chhing*[10]) is dubbed white sugar (*pai sha-thang*[11]), and next clear (*tshu-chhing*[12]) which is almost black goes by the name wet tail (*fên wei*[13]).

The whitest sugar is dried in the sun and becomes as fine as powder snow. That sold to [countries] on the eastern and western ocean routes is known as ocean sugar (*yang-thang*[1]). The next whitest is sold within the Empire. Hard and clear sugar with alternate shades of yellow and white which has congealed to form large lumps is termed ice sugar (*ping-thang*[14]), and is also known as sugar candy (*thang-shuang*[15]).

The Chinese preference for darker sugars, which retained most of the impurities, must have diminished demand for the best white sugar on the home market. Also, perhaps the profits from the price differentials between China and abroad made it more attractive to export white sugar rather than sell it at home. The same source listed the various types of sugars sold on the markets in Kuang-Tung province:[b]

Shops in the market places of Kuang-Tung sell cocoon sugar (*chien-thang*[16]). It is nest silk sugar (*kho-ssu thang*[17]). That which is boiled down and made into delicate threads (*thiao tzu êrh ling lung chê*[18]) are known as sugar tubes (*thang-thung*[19]). That which is blown and made hollow in the middle is called blown sugar (*chui-thang*[20]). Small solid ones are called sugar grains (*thang li*[21]), while the large ones are known as sugar melons (*thang kua*[22]) ...

Sesame sugar (*chih-ma thang*[23]), cow's hide sugar (*niu-phi thang*[24] [sugar candy]), excellent sugar (*hsiu-thang*[25]), luxuriant sugar (*tshung-thang*[26]), black sugar (*wu-thang*[27]) and other sugars are taken as snacks (*tsa shih*[28]).

Luxuriant sugar (*tshung-thang*[26]) from Chhao-Yang[29] [county, Chhao-Chou prefecture[30]] is extremely white and without impurities, In the mouth it melts as smoothly as snow sprinkled with water.

[a] *KTHY*, p. 690.

[b] *KTHY*, p. 389. The first part of this passage has been quoted earlier in the section on 'Sugar as Confectionery', p. 78.

[1] 洋糖	[2] 煮煉	[3] 飴	[4] 濁	[5] 黑片糖
[6] 清	[7] 黃片糖	[8] 一清	[9] 赤沙糖	[10] 雙清
[11] 白沙糖	[12] 次清	[13] 濕尾	[14] 冰糖	[15] 糖霜
[16] 繭糖	[17] 窠絲糖	[18] 條子而玲瓏者	[19] 糖通	[20] 吹糖
[21] 糖粒	[22] 糖瓜	[23] 芝麻糖	[24] 牛皮糖	[25] 秀糖
[26] 蔥糖	[27] 烏糖	[28] 雜食	[29] 潮陽縣	[30] 潮州府

Excellent sugar (*hsiu-thang*[1]) is from Tung-Kuan [county[2], Kuang-Chou prefecture[3]], and sugar tubes (*thang thung*[4]) from Kuang-Chou[5] ...

All the sugar households (*thang-hu*[6]) dry sugar in the sun, use a draining cone (*lou*[7]) to drip off the molasses (*ti-chhu shui*[8]) and store it in warehouses. In spring they advance funds to sugarcane-growing peasants to make sugar and collect the profits from it [when they receive the sugar] in the winter (*chhun i thang-pên fên yü chung-chê chih nung tung êrh shou chhi thang li*[9]). New [shipments of] sugar come in again before the old sugar has been exhausted. Many of those who run sugar houses (*thang fang*[10]) have made their fortunes from this [trade].

By now it should be clear that the production and consumption of sugar became widespread in Kuang-Tung province by the close of the +17th century. The great array of sugars manufactured found favour with consumers in the home province as well as in other parts of the Empire. Certain grades of Kuang-Tung sugar, such as double clear (*shuang-chhing*[11]) and piece sugar (*phien-thang*[12]), achieved fame throughout the Empire, even appearing in a merchant route book of the +18th century.[a] Sugar production spread out and diversified over the province to such an extent that places like Chhao-Chou prefecture[13] rapidly acquired fame as speciality areas. The sugar trade turned into such a profitable activity that in efforts to secure stable supplies merchants encouraged production by advancing funds to peasants to obtain sugar for sale on the market. The above passage is the earliest reference in China to the production of sugar under a putting-out system, the principal arrangement for its manufacture until the 20th century.

The first half of the Khang-Hsi[14] era (until c. +1690) exhibited all the characteristics of a depression with a decline in the price of all commodities, including sugar.[b] The disruption to the south-east seaboard by the anti-Chhing activities of men such as Chêng Chhêng-Kung[15], and the revolt of the three feudatories[16] (+1673 to +1681), severed the coastal sugar-producing areas from their mid and north China markets. This naturally caused a slump in the domestic sugar trade that continued from +1644 until +1684. In this year the rescission of the strict ban on the coastal and overseas junk trade issued by the Chhing dynasty in +1656 enabled the start of the commerce in sugar within China by sea again. Despite these prohibitions, Chinese sugar found its way overseas to Japan and the Philippines through the seaborne empire of the Chêng family who sold it to the Dutch ensconced on southern Taiwan from +1624 until +1662. After ousting the Dutch, the Chêng family continued using Chinese technology and labour to make sugar for export.[c] After the Chhing dynasty obtained sover-

[a] See the +1787 edition of the *Shih Wo Chou Hsing*, ch. 3, pp. 12a–12b.
[b] For an exposition of the Khang-Hsi depression see Kishimoto-Nakayama (1).
[c] Daniels (2).

[1] 秀糖 [2] 東莞縣 [3] 廣州府 [4] 糖通 [5] 廣州
[6] 糖戶 [7] 漏 [8] 滴去水
[9] 春以糖本分與種蔗之農、冬而收其糖利 [10] 糖房 [11] 雙清
[12] 片糖 [13] 潮州府 [14] 康熙 [15] 鄭成功 [16] 三藩

eignty over the island in +1683, Chinese settlers expanded sugar production, and the government did nothing to hinder progress. From +1719 we find that Fukienese sugar boats sailing north to Chekiang and Chiang-Nan were exempt from paying customs duty when stopping at Amoy, even though the cargoes presumably originated in Taiwan.[a]

Prohibitions on coastal junk trade encouraged the export of sugar from Chiang-Hsi and Kuang-Tung to the Chiang-Nan markets via inland waterways,[b] but the revolt of the three feudatories completely halted imports from South China. A few districts of Chiang-Nan responded by commencing sugar production themselves, a sort of import substitution policy so to speak. Yeh Mêng-Chu[1] (+1624–?) in his *Yüeh Shih Pien*[2] (A Survey of the Age) of c. +1690 wrote of his own district, Shang-Hai county[3] in Sung-Chiang prefecture[4];[c]

> Sugar is made from the expressed juice of sugarcane (*thang-chê*[5]), and is produced in the various prefectures of Chiang-Yu[6] [Chiang-Hsi] and Ling-Nan[7] [Kuang-Tung], but this place has never had it. During the second lunar month, spring +1676 the army in Kuang-Tung mutinied, obstructing the road from Chi-An[8] in Chiang-Hsi [i.e. the route from Kuang-Tung] causing a sudden rise in the price of sugar. People carrying seed sugarcane (*chê-chung*[9]) returned and planted it near the [Huang-]Phu river[10] in my county where it grew well (*chhêng lin*[11]). They crushed the juice according to the [usual] method (*i fa ya chiang*[12]), boiled it into white sugar, and obtained great profits from its [sale]. But they were unable to make sugar with a top white (*shang pai*[13]) colour, and I think that it was due to the climate (*ti-chhi shih jan*[14]).
>
> After the suppression of the [three feudatories revolt] and the return to normal, sugar from Kuang-Tung arrived in large quantities, but the growers have not stopped even today, because the price of [sugar made by] cultivating sugarcane and boiling it at this place is still cheaper than that brought in from outside; it is most popular around Liu-Li bridge[15] and Chou Crossing[16] east of the [Huang-] Phu river.

Agriculturalists in Shang-Hai county reacted quickly to changes in market conditions probably because of their proximity to the large urban centre of Su-Chou[17]. Yeh Mêng-Chu neglected to relate who transferred the sugar-making techniques, but the locals did not completely master the art for they only succeeded in manufacturing inferior quality white sugar. In any case, sugar manufacture in Shang-Hai county served merely as a makeshift measure to cope with a temporary shortage, and we hear little of it hereafter for sugar imports soon recommenced and sugarcane cultivation never became a feature of Chiang-Nan agriculture.

[a] Khun Kang (*1*), p. 8224.

[b] The +1682 *Yü-Tu HC*, ch. 1, pp. 36a–36b mentioned the Shan-Hsi merchants and other buyers from Chiang-Nan purchasing sugar during the period of prohibition; see below, pp. 106–7, for a translation of the relevant passage.

[c] *Yüeh Shih Pien*, p. 167.

[1] 葉夢珠 [2] 閱世編 [3] 上海縣 [4] 松江府 [5] 糖蔗
[6] 江右 [7] 嶺南 [8] 吉安 [9] 蔗種 [10] 黃浦江
[11] 成林 [12] 依法軋漿 [13] 上白 [14] 地氣使然 [15] 六里橋
[16] 周渡 [17] 蘇州

The domestic sugar trade recovered by the last years of the +17th century, and sugar thereafter became the staple southern commodity in the intra-regional coastal trade between north and south China which expanded greatly during +18th and 19th centuries. In fact sugar may well have been the principal southern commodity responsible for the creation of the coastal trade in the first place. Merchants exchanged sugar from Kuang-Tung and Fukien for cotton from Chiang-Nan and soya beans from north China. Chhu Hua[1], a native of Shang-Hai county in Chiang-Nan, in his *Mu Mien Phu*[2] (Treatise on Cotton) of the +18th century wrote:[a]

> In the second and third lunar months [March to April] people from Fukien and Kuang-Tung bring sugar candy (*thang-shuang*[3]) [to Shang-Hai] for sale. In autumn they purchase only ginned cotton (*hua i*[4]), not cotton cloth (*pu*[5]), to carry home. Bales of cotton are loaded onto countless numbers of ships with large turrets (*lou-chhuan*[6]). This is because the Fukienese and Cantonese are able to spin and weave it into cloth themselves.

Sugar clearly played a vital role in a trading network based on the intra-regional division of labour in specific agro-industrial crops. The climatic and economic unsuitability of commercial cotton cultivation in Fukien and Kuang-Tung, and sugarcane in Chiang-Su, prescribed the pattern of this division of labour. Sugar-making households traded their sugar for imported ginned raw cotton which they then carded, spun and wove into cloth during the slack season, thereby making full use of their own time and labour. As W. H. Mitchell put it in his oft-cited report of 1852 to Sir G. Bonham, the characteristic feature of sugar production in Fukien was 'its exquisite dove-tailing with the other pursuits of the farmer'.[b] The synchronisation of agro-industrial production depended on the ability of peasants in Fukien and Kuang-Tung to spin and weave cotton cloth. Soya beans constituted the principal northern product shipped to the Chiang-Nan region where they were processed into bean curd, pressed for oil and the residue applied as a fertiliser on cotton fields. In addition, Kuang-Tung and Fukien imported soya bean residue for application as a fertiliser on sugarcane fields during the 19th century. The basic pattern was for ships carrying sugar to leave Kuang-Tung and Fukien during the fourth and fifth lunar months proceeding north to Chekiang, Chiang-Su, Shan-Tung, Tientsin, and thence to markets on the Liao-Tung peninsula. They returned in the ninth and tenth lunar months laden with raw cotton from Chiang-Nan and soya bean residue, medicine, fruit and other northern produce.[c]

[a] *Mu Mien Phu*, p. 11b.

[b] Original text reproduced in Tanaka (*2*), p. 313.

[c] For the north–south coastal junk trade during the +18th and first half of the 19th century see Matsuura (*1*); (*2*), p. 52; (*3*), pp. 40–7; Miyata (*1*), pp. 4–5; and Martin, R. Montgomery (1), vol. 2, pp. 132–5. For use of soya bean residue as a fertiliser see Miyata (*1*), p. 5 and Adachi (*1*), p. 48.

[1] 褚華 [2] 木棉譜 [3] 糖霜 [4] 花衣 [5] 布
[6] 樓船

The inland sugar trade along the mid and upper reaches of the Yangtse river also flourished during the +18th century along with the general increase in commerce that accompanied the rise of Hankow.[a] The *Shih Wo Chou Hsing*[1] (Travelling Everywhere On My Own) of +1787, a route book written specifically for merchants, listed Ssu-Chhuanese sugar (*Chhuan thang*[2]), pure sugar (*chieh-thang*[3]), double clear (*shuang-chhing*[4]), ice sugar (*ping-thang*[5]), bucket sugar (*thung-thang*[6]) and honey as important articles of commerce at the three large mid-Yangtse commercial centres of Han Chen[7] (Hankow[8]), Sha-Shih[9] and Hsiang-Than[10]. The transactions for the sale of the last four types of sugar lay in the hands of the Kuang-Tung and Fukien guilds.[b] Double clear sugar was even brought from Kuang-Tung, the best deriving from Chin-Ching[11] and Shih-Lung[12].[c] At roughly the same time, by the +1780s at least, Ssu-Chhuanese sugar emerged as a strong competitor on the mid-Yangtse market. In 19th century Ssu-Chhuan we find instances of Fukienese immigrants amassing considerable fortunes from the trade in sugar and tobacco by utilising networks of fellow provincials.[d] In the general trade slump of the 1840s following the opium war, cheap Ssu-Chhuanese sugar undercut Taiwanese sugar on the north China markets causing further hardship to the islanders who at the time also suffered a fall in rice exports.[e] These changes underline the important position that the mid-Yangtse sugar market assumed in the intra-regional sugar trade from the second half of the +18th century.

The spread of new sugar-making technologies

The appearance of new agricultural methods, sugarcane crushing, clarification and claying techniques were pre-conditions for the great expansion of sugar production after the +16th century. During the +15th and +16th centuries people in Fukien, the leading contemporary sugar producer, integrated these techniques into a technological package designed for efficient commercial production in an expanding domestic market. From the late +16th century this new technology diffused from the Fukienese core area to the neighbouring provinces, and even overseas to countries in East and South-East Asia.[f] We

[a] For rise of Hankow from the late +18th century see Rowe (1).

[b] *Shih Wo Chou Hsing*, ch. 3, p. 1b, ch. 3, p. 3b, ch. 3, p. 5b.

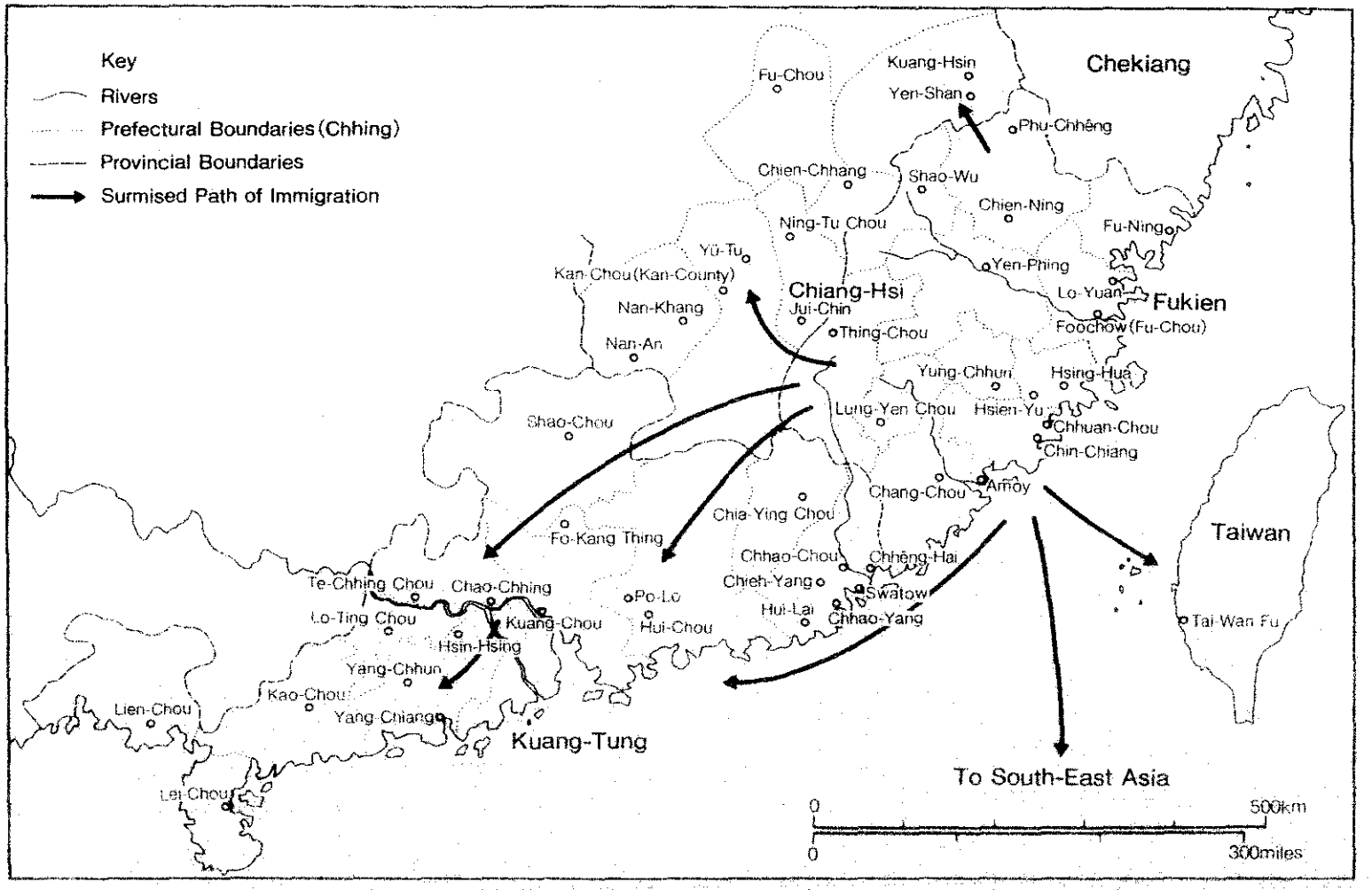
[c] *Shih Wo Chou Hsing*, ch. 3, p. 12a. The 1879 *Kuang Chou FC*, ch. 15, pp. 13b–14a also recorded that merchants shipped sugar, fruit, steel and other products to Hankow and Chhang-Sha as well as other mid and north China ports.

[d] For example see the case of Lu Mou[13], from Ting-Chou prefecture[14] in Fukien who arrived in Yün-Yang county[15], Khuei-Chou prefecture[16] during the Tao-Kuang[17] period (1821 to 1850), 1935 *Yün-Yang HC*, ch. 26, pp. 7b–8a.

[e] Daniels (2), p. 54.

[f] For the spread of Chinese sugar-making technology overseas see (*f*), below.

[1] 示我周行 [2] 川糖 [3] 結糖 [4] 雙清 [5] 冰糖
[6] 桶糖 [7] 漢鎮 [8] 漢口 [9] 沙市 [10] 湘潭
[11] 金井 [12] 石壩 [13] 盧牟 [14] 汀州府 [15] 雲陽縣
[16] 夔州府 [17] 道光



Map 3. Surmised path of immigration of Fukienese in the +16th and +17th centuries, showing prefectures and counties in which they began sugar production in Chiang-Hsi and Kuang-Tung provinces (Chhing prefectural boundaries).

will treat the new technologies under their appropriate heading later, and here only discuss the question of domestic human migrations. Local gazetteers revealed a close correspondence between the movement of peasants from Fukien to Chiang-Hsi and Kuang-Tung and the growth of sugar making in these provinces from the late +16th century. The fine studies by Tajiri Tōru[1] show that Fukienese transmitted the techniques for the cultivation and manufacture of indigo to Chiang-Hsi in the latter half of the +15th century, and those for tobacco in the +17th and +18th centuries.[a] The migration of Fukienese peasants to these provinces played a key role in boosting contemporary sugar production in the following three ways.

1 By immigrating and engaging in the commercial production of sugar Fukienese peasants introduced advanced techniques of sugarcane cultivation and sugar making into these neighbouring provinces. This expanded the total area of land utilised for sugarcane cultivation.
2 The Fukienese with their advanced technology and abundant labour tended to control, even to monopolise, cane growing and sugar making in some areas, particularly Chiang-Hsi.
3 In other areas, such as Kuang-Tung, the immigrants settling into life in their adopted homes imparted their technological skills to the local inhabitants.

From the late Ming onwards famine, overpopulation, land shortage, poverty and other economic factors forced peasants in Fukien to emigrate. Local gazetteers of their new domiciles variously described the residential status of such immigrants as 'temporarily abiding' (*chhiao chü*[2]), 'mobile sojourn' (*liu yü*[3]) and 'drifting sojourns' (*fu yü*[4]). These terms distinguished them from local people, and emphasised their position as outsiders in the community. Though these sources often neglected to mention from which part of Fukien the immigrants hailed, judging from their subsequent occupation they probably came from sugarcane-growing areas. Clearing waste land to grow sugarcane and manufacture high-grade sugar was common procedure in Fukien during the late +16th century. The *Min Shu* of +1631 related that in Chhüan-Chou prefecture, one of the major Fukienese sugar-producing areas during the +15th and +16th centuries, 'people living near the hills open up hard and barren land to plant sugarcane and boil sugar'. It also added that 'black and white sugar [from here] is marketed all over the Empire'.[b] Peasants put skills acquired by engaging in such operations at home to use when they emigrated.

Commercial production of sugar required labour and technical skill. By the early +17th century agriculture in Fukien had become labour intensive with peasants seeking increased yields through irrigation, weeding and fertilising.[c]

[a] Tajiri (*1*), pp. 48–9, pp. 72ff and Tajiri (*2*), *jō*, pp. 6–7.
[b] *MS*, ch. 38, pp. 2a–2b.
[c] Rawski (1), pp. 44–56.

[1] 田尻利 [2] 僑居 [3] 流寓 [4] 浮寓

Under prevailing economic conditions, commercial production of sugarcane and sugar could not be undertaken without a knowledge of these labour-intensive methods of cultivation. The passage from the +1682 Yü-Tu county gazetteer cited below makes it quite clear that local peasants were not always willing to put forth the extra labour required for cultivating sugarcane. This resulted in Fukienese immigrants monopolising sugarcane growing in parts of Chiang-Hsi, even as late as the first half of the 19th century because local peasants lacked the necessary agricultural skills. In Kuang-Tung, on the other hand, there seems to have been rapid technological transfer and diffusion among the local people as the Fukienese cease to be mentioned after the +17th century. Next let us examine the situation in these two provinces individually.

Chiang-Hsi

By the early +1680s sugarcane was cultivated in three prefectures in Chiang-Hsi all located relatively close to the Fukien border; Yü-Tu county[1] in Kan-Chou prefecture[2] and Yen-Shan county[3] in Kuang-Hsin prefecture[4] produced sugar while Fu-Chou prefecture[5] only grew sugarcane.[a] In Yen-Shan and Yü-Tu counties the cultivation of sugarcane and sugarmaking lay in the hands of the Fukienese.[b] In Yü-Tu, a county well known for its sugarcane since the early +6th century,[c] Fukienese immigrants gained complete control over sugarcane growing and sugar making to the exclusion of the local people by the mid +17th century. The +1682 gazetteer for Yü-Tu county lamented.[d]

During peaceful times in the past [before the turbulence of the late Ming] people from other prefectures occupied over half [of the profits from] the local produce. In autumn and winter the river is covered with convoys of large ships coming down one after another, but the profits go to people from neighbouring prefectures. Though [the profits] are now gradually returning to the masters of the land [i.e. the local inhabitants], the lives of the people have been influenced by natural calamities from time to time. This has resulted in extremely few [local] people engaging in agriculture despite having fertile land. Oh, where can we find men like Kuan Chung[6] and Shang Yang[7]![e]

At present we cannot even obtain a so-called internode of 'the sugarcane most superior in flavour and colour' recorded by the *Nan-Khang Chi*[8]. At various places near the river, the deep green [of sugarcane leaves] stretches out into the distance. The cultivators of it [and the sugar makers] are all Fukienese. Those that transport [the sugar]

[a] See the +1682 *Yü-Tu HC*, ch. 1, pp. 36a–36b, the +1683 *Yen-Shan HC*, ch. 3, p. 36a and ch. 3, p. 43b, the +1683 *Chiang-Hsi Thung Chih*, ch. 8, p. 68a and the +1688 *Fu-Chou FC*, ch. 8, p. 4b.

[b] The +1683 *Yen-Shan HC*, ch. 3, p. 43b makes it clear that production began after the arrival of the immigrants: 'Sugar (*sha-thang*): The Fukienese people came to Yen-Shan and cultivated sugarcane. During the winter months they boil the juice to make sugar. It is not of the best quality.'

[c] The *CMYS* of c. +535 wrote of Yü-Tu, 'the soil is fertile and particularly well suited to sugarcane. Sugarcane of other provinces is inferior in flavour and colour' (92.25.2).

[d] +1682 *Yü-Tu HC*, ch. 1, pp. 36a–36b.

[e] Kuan Chung, and Shang Yang, also called Kung-Sun Yang[9], were Legalist statesmen of the Spring and Autumn and Warring States periods who advocated policies of enriching and strengthening their States.

[1] 雩都縣 [2] 贛州府 [3] 鉛山縣 [4] 廣信府 [5] 撫州府
[6] 管仲 [7] 商鞅 [8] 南康記 [9] 公孫鞅

away are all big traders and merchants from the north-west and Chiang-Nan. The annual value of this commerce amounts to no less than ten thousand taels (*chin*[1]) in naked wealth (*chih chhiang*[2]). The natives of Yü-Tu have never obtained even a little profit from it. Is this not because the natives of Yü-Tu are too fond of [saving] their labour and willingly forsake the profits to be gained from it?

The Fukienese, the cultivators and the sugar makers, shared control of sugar production with outside merchants who purchased it for sale on the mid-China markets. Merchants 'from the north-west' probably refers to the famous Shan-Hsi merchants[3] who had engaged in the inter-regional indigo and sugar trade in southern Chiang-Hsi since the late Ming.[a] The connections with intra-regional markets probably began in the mid +17th century when the ban on coastal trade would have been an incentive to produce sugar for Chiang-Nan consumers in inland areas accessible by river transport.

Why were the Fukienese able to maintain their position as the main cane growers and sugar manufacturers? The answer seems to lie in their position in the land tenure system. The +1710 gazetteer for Nan-Khang county[4] in Nan-An prefecture[5] in the south of the province near the Kuang-Tung border stated:[b]

Nan-Khang recently [began] to produce sugarcane, and annually boils as much as several 10,000 *tan*[6] [approx. 1,200 to 1,800 tonnes] of sugar (*thang*[7]). It also produces a fruit (*kuo*[8]), called *lo hua shêng*[9] or born from fallen flowers [i.e. the peanut],[c] which is suitable for planting on poor soil. The vine-like stem extends and bears a yellow flower above ground, and all the four petals enter the soil where the pods form (*chieh-shih*[10]). Its name is also beautified to *chhang shêng kuo*[11] or long-bearing fruit.

[Merchants] carry these two products [i.e. sugar and peanuts] to distant [markets] and the profits are enormous. None of the earlier gazetteers recorded them,[d] but all the sugarcane is grown on land leased [from local people] by the Fukienese, who attract large numbers of bandits. It is easy to hide villains in the large forests of sugarcane that grow bushy and high. Over a hundred people assemble when sheds are erected to squeeze sugar (*ta phêng chiao thang*[12]). Local wardens (*ti-fang*[13]) find it difficult to examine and investigate them. In addition, travelling merchants frequently suffer losses in their commercial transactions due to swindling by the Fukienese, and accusations and law suits never cease. All of this derives from the local villagers (*li-jen*[14]) profiting from the heavy rents [which makes them] unwilling to alter their occupations. If they would only change to growing beans, peas, wheat and barley (*tou mai*[15]), though the profit would be small the villagers would attain the happiness of peace and quiet.

As in Yü-Tu county, the Fukienese commenced their sugar-making activities here during the +17th century. Ignorance of the requisite agricultural and man-

[a] Fujii Hiroshi (*1*), pt 1, pp. 24–5.
[b] The +1710 *Nan-Khang HC*, ch. 3, pp. 17a–17b. This source was first cited in Tajiri (*2*), *jō*, pp. 8–9, fn. 22.
[c] For an account of *lo hua sheng* see Vol. 6, pt 2, pp. 516–17.
[d] The only extant earlier gazetteer for Nan-Khang is the edition of +1555.

[1] 金 [2] 裝鏹 [3] 山西商人 [4] 南康縣 [5] 南安府
[6] 石 [7] 糖 [8] 果 [9] 落花生 [10] 結實
[11] 長生果 [12] 搭棚絞糖 [13] 地方 [14] 里人 [15] 荳麥

ufacturing technologies prevented local landlords from participating in production, and anyway it paid them to do so for they received handsome rents. This in turn discouraged the diffusion of sugar technology to the local people. The position of the Fukienese as tenants ensured their control over technological skills, and though their activities generated some economic prosperity, local officials regarded their presence as generally disruptive to society. Chhing bureaucrats dreaded large gatherings of labourers of any kind, sugar-mill workers included, as we shall show below.

The administrator and botanist, Wu Chhi-Chün[1], in his *Chih Wu Ming Shih Thu Khao*[2] of 1848 plainly indicated that the pattern of Fukienese domination of production in Chiang-Hsi continued into the first half of the 19th century.[a]

> Sugarcane is cultivated as far as the eye can see on the sandy and pebbly soil (*sha lo*[3]) beside rivers which do not grow grain crops in Fukien and Kuang-Tung. Passers-by who pull out stalks to quench their thirst are not reproached (*pu-chiao*[4]). In the Chang-Kung[5] region [north-west of the administrative walled city of Kan county[6]] immigrants from Fukien (*min-jen chhiao-chü-chê*[7]) gain their livelihood from sugarcane. They have set up ovens (*tsao*[8]) and grinders (*mo*[9]) to boil sugar on the land there. The [Fukienese] owners cut [their sugarcane] first and the villagers are allowed to pick up the stalks left over by them afterwards. To do otherwise would incur a great loss of profit. As a result [the Fukienese] are somewhat parsimonious with their sugarcane. The local people are [therefore] envious of the monopoly exercised [by the Fukienese] over profit made in their county. I once asked the local people [about the reasons for the monopoly] and could hardly believe their reply; they all said they were not skilled at growing sugarcane.

Fukienese immigrants, presumably mostly tenants as in Nan-Khang county, inspired the ingress and expansion of the commercial production of sugar in Chiang-Hsi between the +17th century and the 1850s. Their agricultural and technical skills established them as the sole producers of sugar with a minimum of interference from others. From the +17th century peasants from Fukien, known as shed people (*phêng-min*[10]), settled in the mountainous areas of Chiang-Hsi as tenants and cultivated a variety of commercial crops such as sugarcane, indigo, ramie, tea, timber and lacquer, in addition to subsistence crops.[b] They could also have helped in the transmission of the new technology.

Kuang-Tung

A similar pattern to that observed in Chiang-Hsi also presented itself in Kuang-Tung during the second half of the +17th century. A number of exam-

[a] Wu Chhi-Chün (2), ch. 32, p. 27b.

[b] See Averill (1) for a case study and for further information, Maeda (1), p. 576. Maeda noted that shed people grew sugarcane in the mountains of Chang-Chou and Chhüan-Chou in southern coastal Fukien during the early +17th century.

[1] 吳其濬 [2] 植物名實圖攷 [3] 沙礫 [4] 不較 [5] 章貢
[6] 贛縣 [7] 閩人僑居者 [8] 竈 [9] 磨 [10] 棚民

ples can be cited for the hinterland to the Pearl River delta. First, let us examine the establishment and expansion of the sugar industry within Chao-Chhing prefecture[1] and surrounding districts from about +1660 until +1750. The +1673 gazetteer acknowledged drifting sojourners from Fukien (*min-jên fu-yü*[2]), who lived by planting sugarcane and making sugar, as the founders of cane sugar production in Tê-Chhing Chou[3] and Yang-Chhun[4] county.[a] We can follow the spread of sugar technology within the same prefecture from Yang-Chhun county[4] to Hsin-Hsing[5] county. The +1758 gazetteer for the latter county stated:[b]

> Formerly no [cane sugar] was made, [but] recently [the art of growing sugarcane and making sugar] has been brought from Yang-Chhun county. This is the first time we have obtained its method of manufacture.

Within the space of less than one hundred years Fukienese immigrants transmitted sugar making to the local people, and it diffused further to other counties within Chao-Chhing prefecture. The +1759 gazetteer for Kuang-Chou prefecture[6] commented in laconic fashion on how swiftly Kuang-Tung peasants had responded to the introductions:[c]

> Cane sugar from Kuang-Tung is sent to all the four quarters of the Empire. Fukienese people started [sugar production in Kuang-Tung, but] now the profits obtained [from the sugar trade in this province] equal those of Fukien.

The process of diffusion patently had borne fruit by the mid +18th century, which was considerably more rapid than in Chiang-Hsi.

Fukienese immigrants also played an important role in frontier areas. They opened up uncultivated land in areas where government control remained weakest and civil disorder rife, and planted sugarcane as a commercial crop. A +17th-century gazetteer for Po-Lo county[7] in Hui-Chou prefecture[8] conceded:[d]

> Sugarcane is produced in the waste land areas. Fukienese people clear the wilderness (*tshao-lai*[9]) and plant it. Most of the other temporary residents (*liu-yü*[10]) turn into bandits. Only those who cultivate sugarcane remain content with their occupation, provide for themselves with their own labour and easily accumulate wealth (*shih li êrh i shan*[11]).

The presence of peasants with a vested interest in land cleared with their own labour, spurred on by the prospect of profits to be obtained from marketing their produce, acted as a stabilising force in newly opened areas without estab-

[a] +1673 *Chao-Chhing FC*, ch. 22, p. 21a.
[b] +1758 *Hsin-Hsing HC*, ch. 28, p. 24b.
[c] +1759 *Kuang-Chou FC*, ch. 47, p. 12a.
[d] +1687 *Po-Lo HC*, ch. 1, p. 69a.

[1] 肇慶府 [2] 閩人浮寓 [3] 德慶州 [4] 陽春縣 [5] 新興縣
[6] 廣州府 [7] 博羅縣 [8] 惠州府 [9] 草菜 [10] 流寓
[11] 食力而易贍

lished villages. As such they must certainly have received bureaucratic sanction to continue growing sugarcane without government interference, which contrasts with the disapproving attitude of the author of the +1710 gazetteer for Nan-Khang county, Chiang-Hsi. Clearly the Fukienese were not always a source of trouble, and different responses by officials must be taken into consideration when evaluating their influence on local society.

The renowned sugarcane dykes and fish pond (*chê-chi yü-thang*[1]) in the Pearl river delta only really opened up after the mid-Ming, and the cases cited earlier show Fukienese immigrants bringing their skills to the drier areas surrounding the Pearl river delta. The new sugar technology probably diffused from these peripheral areas to the delta region. By the 19th century most of the sugarcane in Kuang-Tung province was grown in the Pearl river delta and its hinterland, in Chhao-Chou prefecture in the north-east, on the Lei-Chou[2] peninsula and on northern Hainan in the south-east.

Sugar production expanded during the late Ming and early Chhing period in the context of the rise of the money economy and the commercialisation of agriculture. Fukienese immigrants promoted production by transmitting the latest agricultural and manufacturing technology and skills, as described in the *Thien Kung Khai Wu* of +1637, to non-sugarcane growing areas and provided the labour for land development. The knowledge then diffused throughout local society. The contemporary practice of solving the problems of feeding a growing population by land clearance in south China was also another dynamic involved. As the Fukienese cleared new land, especially near rivers, they found sugarcane along with tobacco, indigo and peanuts more profitable than food crops such as rice. Sugarcane attained popularity as a crop for cultivation on cleared land because the fields did not require long preparation as with paddy rice, and the wood from chopped trees served as fuel for sugar boiling.

This pattern of the spread of sugar technology by Fukienese immigrants had a spin-off effect, and played a significant role in expanding the total area of land under sugarcane cultivation. The process of technological diffusion promoted the great expansion of the Chinese sugar market during the +18th century, and even continued through to the early 19th century in certain areas like Chiang-Hsi and Taiwan. The increase in total area of sugarcane land and the spread of cultivation skills by the early 19th century laid the foundation for the sharp growth of sugar production in Kuang-Tung, Chiang-Hsi and Taiwan between the 1870s and 1890s when demand on the overseas as well as the domestic market rose. The close connection between immigration and the expansion of production was by no means peculiar to sugar making in Kuang-Tung and Chiang-Hsi. Rather it formed part of a larger post +16th-century pattern of agricultural and handicraft development which gained impetus from

[1] 蔗基魚塘 [2] 雷州

technological transfer via influxes of agricultural, artisan and merchant immigrants who spread technology, labour and marketing skills.[a]

Geographical location of raw and refined sugar production

In China raw sugar was made in the countryside and clayed sugar in urban areas.[b] This locational pattern can be traced from the practices of immigrant Chinese in South-East Asia. Chinese sugar manufacturers in Cochin-China during the +18th century, and in the Philippines during the early 19th century, bought sugar from the countryside.[c] John White, who visited Manila in 1819, observed the transportation of raw sugar from plantations to urban areas for claying:[d]

> It [sugar] is then in its raw state, in which the contractors purchase it from the country people, and clay it in the suburbs of the city, in large buildings called Camarines, erected for that purpose: they produce three qualities, first, second and third. It is for the advantage of a supercargo, who selects for the American or European markets, to purchase all the first quality, even at a considerably higher rate, on account of its superior character in those countries, as well as saving freight.

The Chinese placed importance on the distinction between black (brown) sugar and white sugar because it signified two different manufacturers. Black sugar was manufactured by the cane growers themselves or by landlords and merchants, while white sugar making usually remained the domain of merchants who had the capital to undertake the operation, and the enterprise to market the finished product. The Chhung-Chên[1] period (+1628 to +1644) gazetteer, for Lo-Yüan county[2], Fu-Chou prefecture[3] Fukien stated: 'People from Hsing-Hua prefecture[4] always purchase (*fan-mai*[5]) [brown sugar] in this county for boiling to make white sugar and sugar candy (*thang-shuang*[6]). As a result [the amounts of these two Sugars] produced [in the county] have increased greatly compared to those previously made.'[e] This source demonstrated that the sale of brown sugar to sugar refiners for making into white sugar and sugar candy existed at least from the early +17th century.

[a] See Perdue (1), pp. 93–135 for Hu-Nan, and Averill (1), for Chiang-Hsi.

[b] In south Taiwan during the Chhing dynasty, manufacturers of white sugar were located in urban areas. Hara (*1*), pp. 22–5 reporting the situation on Taiwan during the late 19th century noted that sugar mills manufacturing brown sugar (*chhih-thang*[7]), called *thang-pu*[8], were located in rural areas while refineries making white sugar and sugarcandy, known as *thang-chien*[9], were built in urban areas. According to Tōgyō Kyōkai (Tōgyō Kyōkai (*1*), p. 238) *thang-chien* were usually permanent structures with brick or clay walls and tile roofs. Many of them had two or three rooms, some with single rooms measuring about 333 sq. metres. Kanda Masao (Kanda (*1*), p. 537) recorded the same rural urban distribution pattern for Ssu-Chhuan during the 1930s where refineries went by the name *lou-phêng*[10].

[c] See Poivre (1), pp. 108–9 for Vietnam, and White (1), pp. 133–4 for the Philippines.

[d] White (1), pp. 133–4.

[e] Quoted from the 1831 *Lo-Yüan HC*, ch. 28, p. 27a.

[1] 崇禎 [2] 羅源縣 [3] 福州府 [4] 興化府 [5] 販買
[6] 糖霜 [7] 赤糖 [8] 糖廍 [9] 糖間 [10] 漏棚

Yet, unlike Europe, China never saw the growth of sugar refining centres close to large consumer areas in central and north China, which relied on raw sugar imported from far-away places, as in the case of Venice in Italy during the +15th and +16th centuries, and Amsterdam in the +16th century.[a] Nor did China promote the development of 'sugar islands' like the English and French sugar colonies in the West Indies which hauled sugar across vast oceans for refining in the home country. The Chinese refined white sugar in urban areas within the sugarcane-growing areas before export to consumer markets in central and north China. Even in the case of Taiwan, which in some respects resembled the Caribbean sugar colonies, manufacturers refined white sugar on the island before shipping. This general pattern of manufacturing on location commenced early, and even today large consumer cities like Shang-Hai do not have as intensive a concentration of sugar refineries as in similar urban centres of the West.[b] Since sugar production took place in sugarcane-growing regions, China never experienced a major conflict of interests between raw-sugar producers and sugar refiners, as occurred with the metropolitan sugar refiners in England and colonial plantation owners during the +18th and 19th centuries. Unlike Europe, beet sugar did not begin to challenge cane sugar until the 20th century in China.

Appellations for the sugar mill in China varied from region to region. They were known as *thang-liao*[1] and *thang-fang*[2] in Kuang-Tung, *thang-pu*[3] in Taiwan and *thang-fang*[2] in Ssu-Chhuan.[c] All of these names referred to the boiling as well as the crushing apparatus. The first character of these compounds, *thang*[4] means sugar, while the second ones *liao*[5] (hut), *fang*[6] (house) and *pu*[7,d] (hut) referred to the building which ranged from temporary to more permanent structures. During the crushing season millers commonly erected simple wooden frames thatched with the leaves and stalks of various types of plants such as the Chinese mallow (*khuei*[8]; *Malva verticillata* L R280) in the cane fields.[e] To facil-

[a] Deerr (1), pp. 451, 453. See Leubuscher (1) for an in-depth study of the reasons for separating raw sugar production from refining. The first known reference to shipping a saccharine material from a sugarcane-growing district to an urban consumer area for refining in China appeared in the Yüan period when cane syrup was sent as tribute from Fukien to the Sugar Bureau in Hangchow for re-boiling into *sha thang*, see *Yüan Shih*, p. 2204. However, this government-sponsored operation was not continued after the Yüan.

[b] There is no clear definition of a refinery. In general parlance there are two types of sugar factories, raw-sugar mills and refineries. The former manufactures raw sugar containing a significant amount of impurities, while the latter processes sugar or syrup rather than sugarcane, and manufactures low impurity, high-grade sugars. This definition breaks down when a factory crushing sugarcane produces a high-grade sugar, as did the Dutch factories in Java.

[c] For Kuang-Tung see *KTHY*, p. 389 & p. 690 and Ku Ssu-Hsieh (1), pp. 34b–35a; for Taiwan see Sugata (1), pp. 1–6 and for Szechuan see Kanda (1), p. 527.

[d] The character *pu* first appeared in an +18th-century work on Taiwan, the *Chhih Chhien Pi Than*, cited in *THSCL*, pp. 52 and 56.

[e] For early +18th-century examples see the +1710 *Nan-Khang HC*, ch. 3, pp. 17a–17b which mentioned sheds set up to squeeze sugar (*ta-phêng chiao thang*[9]) and Ku Ssu-Hsieh (1), pp. 34b–35a which indicated erecting mills in cane fields to press sugarcane (*ta-kai khuei liao cha thang*[10]) in Hsin-Hui county[11] near Kuang-Chou.

[1] 糖寮 [2] 糖房 [3] 糖廍 [4] 糖 [5] 寮 or 寮
[6] 房 [7] 廍 [8] 葵 [9] 搭棚絞糖 [10] 搭蓋葵寮榨糖
[11] 新會縣

itate moving mills elsewhere when necessary the crushing and boiling equipment had to be transportable. Some examples of brick-built sugar-boiling houses appeared in Taiwan during the late 19th century when sugar exports from the island increased to a great extent.

The portability of the Chinese sugar mill helped mould the locational pattern of raw and refined sugar production. All the crushing apparatus, no matter whether vertically mounted double-roller mills or *frangouriniers*,[a] could be dismantled easily and transported by boat or bullock cart. The ability to take the mill to the field enabled the conversion of sugarcane into sugar on the spot, which meant it could be either marketed as it was, or sold to refiners. This technological factor reinforced the Chinese pattern of producing raw sugar in numerous small mills scattered over wide rural areas and refining it in urban areas. Let us look at this aspect of Chinese sugar milling in further detail.

In many of the sugar-producing areas of China sugarcane growers commonly hired skilled workers, and in some cases the crushing apparatus and boiling pans they carried with them as well. Charles Gustavus Eckeberg, the captain of a Swedish East India Company ship, who visited Kuang-Chou three times during the +1740s, related:[b]

> When the canes began to grow yellow [...] they were cut; for when they stood longer, they grew mouldy at the root. They grow from eight to twelve feet high. Some sampane cargoes of canes are brought together to a convenient place on the river side; there they build a hut of bamboo and mats, at one end of which they make a furnace with two great iron-boilers; and at the other an even floor of a considerable size laid with planks, over which two oxen draw an angulated roller of hard wood[c] ... When no canes remain in the place where they are, they remove the house again, and proceed further with all their implements. These sugar-bakers travelled about in the country, and boiled the sugar out of the country people's canes, leaving it to be refined by other sugar-bakers, and made into fine and coarse powder-sugar.

Staunton in his account of the +1797 embassy to China led by Lord Macartney confirmed that this practice was not merely confined to Kuang-Tung province. He described sugar mills in the area south of Hangchow prefecture in Chekiang in the following terms:[d]

> The cane plantations in China belonging to individuals, were of very little extent; and the expence of erecting sugar mills too heavy to have one upon each plantation. The business of extracting the juice of the cane, and of boiling it into sugar is, there, a separate undertaking from that of him who cultivated the plant. The boilers of sugar travel about the country, with a small apparatus sufficient for their purpose, but which a West India planter would consider as inefficacious and contemptible. It is not a mat-

[a] I have called the *khun nien* (hard wooden rollers) the *frangourinier* to distinguish it from the edge-runner mill.

[b] Osbeck (1), pp. 296–7.

[c] This was a *khun nien*[1] or *frangourinier*.

[d] Staunton (1), vol. 3, pp. 292–3.

[1] 輥輾

ter of great difficulty to travel with this apparatus, as there are few plantations of which some part is not accessible by water-carriage. A few bamboo poles and mats, are deemed sufficient for a temporary building; within which, at one end, is fixed a large iron cauldron, with a fire-place and flue, and about the middle a pair of cylinders or rollers, fitted vertically in a frame ... The sugar boiler endeavours to enter into an agreement with several planters at a time; so that his works, erected near the centre of their several plantations, may serve them all without changing his establishment. During the time he is employed, the servants and children of the planter are busily engaged in carrying canes to the mill.

This pattern of itinerant sugar makers supplying the equipment and special skills for sugar making arose due to a lack of capital and skill on the part of the immediate producer. Chinese peasants lacked the excess funds required for investing in the outlay of a sugar mill that would run for less than a quarter of a year. Of course, landlords did set up their own mills, and as we shall see below, peasants, in particular in areas such as Taiwan, did jointly invest in sugar mills. The ability to transport the sugar mill made it easy for sugar production to expand and contract rapidly in accordance with the needs of the market.[a]

The transportation of the sugar mill to the cane field did away with the necessity of heavy capital outlay in building roads and railways to transport sugarcane to a central mill, essential facilities in plantation economies and modern sugar industries. This was a key factor in the great expansion of sugar production in China, as neither the State nor merchants provided capital outlay for the type of infrastructure necessary for production arranged around large central sugar mills. The notoriously bad condition of roads in pre-modern China, coupled with the fact that peasants invariably cultivated sugarcane in separate fields scattered over a fairly wide area, made it far easier to transport small mills to the field rather than trying to move the sugarcane to a large central mill. In 1878 Elles and Co., a trading company in Amoy, put the situation succinctly in a letter answering complaints from a sugar refiner in Sydney, Australia, about the irregular quality of raw sugar imported from southern Taiwan.[b]

The cane is grown on plantations of various sizes, but mostly on very small holdings of not more than a few acres. The cane is crushed and the juice boiled on the spot. The mill stones being carried from place to place and the furnaces temporarily constructed. The reason for this is that there are practically speaking no roads in the island bigger than sheep tracks and it would be next to impossible to carry the cane by coolie labour to a large central mill at any great distance from the plantation. There are no conveniences for storing the sugar, except at the ports of shipment, so that it comes down lot by lot as made and this will explain to you the variation in colour. It would be practically impossible to go about the country buying up small parcels of sugar, even if the makers had the power of sale, but this as you will have understood from our last letter

[a] Daniels (*r*), pp. 95–6.

[b] Letter from Elles & Co. to Grafton Ross the General Manager of the Colonial Sugar Refining Company dated Amoy 15th July 1878 in CSR Deposit 142/2671, Archives of Business and Labour, Australian National University, Canberra.

they rarely have, at any rate until they have satisfied the advances which have been made to them to enable them to meet the expenses of growing the cane and making the sugar.

This arrangement facilitated the merchant practice of encouraging peasants to undertake sugar production when sugar prices rose, and discouraging them as soon as they fell, because the latter would not be losing money on invested capital. The small capital outlay required by immediate producers also meant that merchants could easily entice peasants to engage in sugar making by advancing funds. In this way merchants could adjust the production of sugar to meet the changing demands of the market.

Organisation of production

Many studies of European colonial sugar plantations in the Caribbean and South America examine the organisation of labour, land and finance.[a] The studies of Sucheta Mazumdar (Mazumdar (1)) for the Pearl River delta and Christian Daniels (Daniels (*1*)(*2*)(*3*)) for Taiwan have explored the situation in China during the +18th and 19th centuries. Here we shall consider the organisation of sugar production with evidence from a number of different regions: Chhao-Chou prefecture[1] in north-eastern Kuang-Tung for the relationship between trade and the advance contract system, and southern Taiwan for land and labour.

Sugar manufacturing in Chhao-Chou prefecture grew into a highly developed enterprise catering for the north and mid-China markets long before the Chhing dynasty opened the port of Swatow to foreign trade in accordance with the treaty of Tientsin in 1858. Though the +1547 gazetteer for Chhao-Chou prefecture made no mention of sugar, by the +1660s Chhao-Chou already manufactured high-quality sugars, *tshung-thang*[2] (sugar candy; extremely white and without impurities) and *wu-thang*[3] (made by refining black sugar with the egg clarification process) that required knowledge of advanced sugar technology.[b] During the early +18th century the production of sugar rose as sugar manufacturing became increasingly market-orientated and more specialised. By the early +18th century Chhao-Yang[4] county had attained fame for its *tshung-thang*, and before the +1760s nine of the eleven counties made white sugar for shipping to markets in Chiang-Nan and Chekiang.[c] In short, by the latter half of the +18th century sugar production had become a widespread activity of increasing importance to the local economy of Chhao-Chou. The growth of the cash economy and the concomitant rise in the demand for

[a] For example see Fraginals (1); Schwartz (1); Watts (1); Galloway (4).

[b] +1547 *Chhao-Chou FC*, ch. 8, n.p. only mentioned sugarcane. References to sugar first appeared in the +1661 *Chhao-Chou FC*, ch. 1, p. 79b.

[c] *KTHY*, p. 389 and the +1762 *Chhao-Chou FC*, ch. 39, pp. 62b–63a.

[1] 潮州府 [2] 蔥糖 [3] 烏糖 [4] 潮陽

sugar, both locally and on inter-regional markets in mid and north China, generated this development.

There were two main markets during the +18th and first half of the 19th century when Chhao-Chou sugar began to be sold in north China. First, as demonstrated earlier, sugar of both high and low quality was consumed in large quantities within Kuang-Tung province. Second, came the large markets in mid and north China linked to Chhao-Chou by a special pattern of trade: the exchange of sugar for raw cotton. In order to obtain a constant supply of sugar, merchants resorted to a sort of advance contract system. The advance of funds to peasants to produce sugar was one of the common ways by which merchants ensured a constant supply of the commodity in +18th- and 19th-century China, so let us take a closer look at it.

The 1815 gazetteer for Chhêng-Hai county[1] noted the close connection between trade and the advancing of funds:[a]

> At the height of the sugar manufacturing season rich merchants and great traders of the county either go around each rural township (*hsiang*[2]) carrying large amounts of funds to buy sugar, or at the assigned time collect the sugar owed for the funds they previously advanced to the sugar mills (*hsien fang chang thang-liao chih chhi shou chih*[3]). Some merchants travel doing business on their own, while others remain in the one place waiting for sellers to come to them. In the third and fourth lunar months [April–May] when the southern winds turn favourable, [merchants] hire large ships, load their sugar bags and proceed up to Su-Chou[4] and Tientsin[5] via the sea route. In autumn when the north-east wind rises, they buy raw cotton and coloured cloth and return to Chhêng-Hai, going all the way down to Lei-Chou[6], Chhiung-Chou[7] [on Hainan island] and other prefectures. One return trip brings double or triple profit, and an exceedingly large number of merchants have established themselves (*chhi chia*[8]) in this way.
>
> Commentary: Brown and white sugar are different. Though both are made by squeezing the juice from sugarcane and boiling it, only people from Chhêng-Hai have mastered the art. As a result exceedingly large numbers of them are hired in Lei-Chou, Chhiung-Chou and other prefectures for sugar boiling.

Merchants obtained sugar under a system of advance payments, and sold it, or more accurately bartered it, on the inter-regional market for cotton goods; the junks sailed north to Su-Chou and Tientsin in April or May with sugar. They returned in the autumn laden with raw cotton and coloured cloth for sale or barter in the sugar-making areas of Lei-Chou and Chhiung-Chou prefectures in southern Kuang-Tung, as well as in Chhêng-Hai county itself. Chhêng-Hai seems to have functioned as a technological as well as the commercial centre of this sugar trade, since large numbers of its skilled sugar masters went to these two prefectures during the crushing season. The merchants who made advance

[a] 1815 *Chhêng-Hai HC*, ch. 6, pp. 8a–8b.

[1] 澄海縣 [2] 鄉 [3] 先放賬糖寮至期收之 [4] 蘇州
[5] 天津 [6] 雷州 [7] 瓊州 [8] 起家

payments to the peasant producers may have been responsible for this movement of technicians. It is not difficult to imagine them providing technological assistance as well as advance payments to ensure constant supplies of good quality sugar.

Chhêng-Hai was by no means the only seaboard county in Chhao-Chou prefecture engaged in this type of trade–production network. Merchants from Chhao-Yang county also exchanged sugar for cloth and raw cotton on the large lower Yangtse markets at Su-Chou, Chia-Hsing[1] and Sung-Chiang.[a] Driven on by the demand on the mid and north China markets, merchants provided the necessary financial and technological assistance for sugar production to expand the trading circle between Kuang-Tung, and the Su-Chou and Tientsin markets. Sugar constituted a commercial commodity of importance sold on the local and inter-regional market.

How did merchants in Chhao-Chou obtain sugar? The 1815 gazetteer for Chhêng-Hai cited above shows that wealthy merchants travelled the countryside to purchase sugar. Merchants had two options open to them. The first was either to buy the sugar from middle men or directly from sugar makers. The second was to advance loans to peasants (*fang chang*[2]), presumably at usurious rates of interest, to get them to cultivate sugarcane and make sugar.[b] As we shall see later, merchants in +18th- and 19th-century Taiwan practised a similar advance payment system, and we may assume that, generally speaking, the manufacture of Chinese sugar took place under much the same sort of merchant control as in Chiang-Nan silk production.[c] To put it simply, the merchant had to advance money to the immediate producer as the latter, usually a small-scale operator driven to engage in commodity production by the need for money, lacked sufficient capital to engage in sugar production on his own. Since these advance payments were in effect loans at usurious rates of interest, the immediate producer soon found it difficult to repay them. Such conditions deprived the immediate producer of the opportunity to increase the size of his operation and accumulate capital, and made him dependent on merchant loans not only for the means of producing sugar, but also for the means to market it. This enabled monopolistic merchants to gain control over the production and marketing in Chhao-Chou. In fact, these merchants belonged to guilds so dominant that they managed to thwart attempts by foreign capital to enter the local sugar trade during the 1870s and 1880s.[d]

[a] 1819 *Chhao-Yang HC*, ch. 11, pp. 7a–7b.

[b] 1815 *Chhêng-Hai HC*, ch. 6, p. 8a.

[c] For production of silk under usurious and commercial capital see Tanaka (2), pp. 89–92.

[d] According to Mayers, Dennys & King (1), p. 238, by the middle of the 19th century the cultivation of sugarcane constituted 'the principal occupation of the inhabitants of the Han delta'. Commercial reports by the British consul in Swatow after 1860 also indicate that sugar was indisputably the staple produce of Chhao-Chou prefecture. European traders found the sugar trade to be monopolised by Chinese merchants who conducted business 'in correspondence with Chinese agencies at New-chwang, Chefou and Shanghai', see (*cont.*)

[1] 嘉興 [2] 放賬

The small-scale nature of Chinese agricultural management in the Chhing period set a different pattern of organisation to that of European plantations in tropical America. From the +16th and +17th century until slave emancipation in the early 19th century the European plantation owner managed the land, agricultural and milling equipment with slave labour. The owners provided all the means of production, received the rewards, and formed a prodigiously powerful elite.[a] In China the investment in sugar production was not concentrated in the hands of a single group, but the risks were spread out amongst a number of people from different social classes; immediate producers (tenants and owner cultivators), landlords and merchants. The need to coerce aboriginal inhabitants into the labour force, or import slaves, never arose as the country abounded in Han Chinese peasants with a high level of agricultural skills more than willing to cultivate crops. To understand the arrangement of land and labour let us look at the case of southern Taiwan from the +17th century through to the middle of the 19th century.

The Dutch East India Company set up a trading station on the island in +1624, and first established sugar production there by bringing Chinese peasants from Fukien to grow sugarcane and manufacture sugar. The company exported the sugar made in south Taiwan to Japan, and Batavia for shipping to Europe and Persia. The celebrated Chêng Chhêng-Kung[1], or Koxinga[2] as he was known to contemporaries, promoted sugar exports after expelling the company from the island in +1662. After +1683 when the Chhing dynasty proclaimed Taiwan a prefecture of Fukien province following the surrender of Chêng Kho-Shuang[3], the grandson of Chêng-Chhêng-Kung, shipments soon commenced to mid and north China. Between the +18th century and 1870 the Chinese domestic market surpassed the overseas market in importance.[b]

The organisation of sugar production in Taiwan derived historically from the land tenure system fostered by Chinese settlement. The system changed over the years in the following way (see Table 9):

(1) In Taiwan land developers, known as *khên-hu*[4], obtained titles for land from local government officials, and then leased their tracts to tenants who cleared it for agriculture, paying their rent in kind or money. After an initial three-year period of exemption land developers began paying tax, and were also account-

Footnotes to page 117 (*cont.*)

Mayers, Dennys & King (1), p. 237. The firm control that Chhao-Chou merchants exercised over the production and marketing of sugar was further attested to by the fact that European merchants never managed to get into the Swatow sugar trade during the 19th century. The *Report on the Trade of the Port of Swatow during the Year 1868*, (*BPP*), vol. 8. No. 5, pp. 55–6 remarked that European merchants at Swatow often complained that they had to buy everything from 'a powerful combination of brokers supported by the mandarins'. Chinese merchants denied their European counterparts the opportunity of direct contact with the immediate producer.

[a] See Watts (1) for the Caribbean; Schwartz (1) for Brazil.

[b] Daniels (2), pp. 51–64.

[1] 鄭成功 [2] 國姓爺 [3] 鄭克塽 [4] 墾戶

Table 9. *Changes in landlord–tenant relations in +18th- and 19th-century Taiwan*

land developer	=	*ta-tsu-hu*
↑		↑
rent		big rent
↑		↑
tenant	=	*hsiao-tsu-hu*
		↑
		small rent
		↑
		sub-tenant

able to the authorities for the conduct of their tenants. These developers erected sugar mills on their land, the operation of which was the joint responsibility of the tenants, who ran the mill according to the shares they had been apportioned by the developer. Written contracts set forth the obligations of all parties concerned, and the tenants were obliged to crush their sugarcane and make sugar at the developer's mill if they chose to cultivate that crop. Outsiders with no share in the mill had to pay the developer a fee if they wished to process their cane.

(2) A dual-ownership system of land tenure, known as the *i-thien liang-chu*[1] or two masters to one field, involving three parties emerged from this land developer – tenant relationship. It can be documented from +1750 in the sugar districts though it must have appeared much earlier on the island. Under this system there were two landlords, the *ta-tsu-hu*[2] and the *hsiao-tsu-hu*[3], and one tenant, known in contracts as the sub-tenant cultivator (*hsien-kêng tien-jên*[4]). The tenant under the old relationship now became a landlord called the *hsiao-tsu-hu* by sub-leasing the land for cultivation to a sub-tenant, collecting the small rent (*hsiao-tsu*[5]) in return. The land developer now known as the *ta-tsu-hu*, or landlord at the top of the ladder, continued to pay the land tax and received his remuneration, known as the big rent (*ta-tsu*[6]), from the *hsiao-tsu-hu* (see Table 9). The *ta-tsu-hu* remained the legal owner in the eyes of the authorities until 1903 when the system was abolished by the Japanese in their re-structuring of the land tax system after acquiring the island from China as a colony.

Since the shares in the sugar mill remained inseparable from the land attached to it, the rights to operate the mill became fragmented amongst a plurality of *hsiao-tsu-hu*. The *hsiao-tsu-hu* exercised firm control over their sub-tenants through written contracts which endowed them with the power to remove them

[1] 一田兩主 [2] 大租戶 [3] 小租戶 [4] 現耕佃人 [5] 小租
[6] 大租

if rent fell into arrears, whereas the *ta-tsu-hu* lacked means of redressing recalcitrant sub-tenants because they held no contractual relationship with the latter, but still had to pay the land tax all the same. As a result the *hsiao-tsu* commanded higher sale value than that of the *ta-tsu* on the land market.[a] The reason usually given for the appearance of the dual-ownership system is that with the passage of time the land developer, who in many cases was an absentee landlord, had lost direct control of his land to his tenants. But I suggest that the elevated position of the *hsiao-tsu-hu* was just compensation for improvements and investments made to the land and mill. The dual land-ownership system in reality recognised the capital investments made by both landlords in sugar production and awarded them each a return from it.

(3) Written proof for joint sugar mills owned and managed by the direct producers (tenants and owner–cultivators) appeared from the +1750s, though contracts must have been drawn up earlier. Japanese investigators at the turn of the century distinguished two types of such sugar mills: the *niu-kua-pu*[1] with between fifteen and forty participants and the *niu-pên-pu*[2] with only two to ten. In the former, the capital for the mill, and all expenses for its operation, as well as all decisions concerning its management were made according to the ownership of basic units known as *niu-kua*[3]. The holder of one *niu-kua* had to provide three water buffaloes, the animal power required to extract one bucket of juice. *Niu-kua* units were not always owned by a single person, but could be jointly held by a number of people. A single sugar mill usually included between five and ten *niu-kua* units, and as the shares in any one of these units could be subdivided, there could easily be as many as thirty or forty members. This afforded tenants and owner–cultivators with meagre capital an opportunity to acquire the means to crush sugarcane. *Niu-pên-pu* were organised along essentially the same lines as *niu-kua-pu*, except that the basic units, the *niu-pên*[4] (carrying the obligation of supplying three water buffaloes), usually were not sub-divided.

With either of these two types of sugar mill, prospective participants would make an agreement, often written, setting out the obligations of each person in the running of the mill.[b] Joint management enabled cane growing owner–cul-

[a] For the values of *ta-tsu* and *hsiao-tsu* rights see Chhên Sheng-Shao (*1*), ch. 6, pp. 22a–22b.

[b] For instance, here is a summary of the basic rules stipulated in a contract for a *niu-kua-pu* sugar mill drawn up in +1760:

(1) The sugar mill is to be managed jointly by all the owners of units. The tax on the sugar mill (*pu-hsiang*[5]) and all operating expenses are to be met by every owner who is required to pay according to the number or portions of units held.

(2) All owners bear joint responsibility for the repayment of money borrowed from guild merchants (*hang*[6]), and for expenses involving dealings with the local authorities. If water buffaloes for powering the mill are stolen every member is duty bound to co-operate in searching for the offender. All expenses involved in delivering the criminal to the authorities are to be divided equally amongst the members. (*cont.*)

[1] 牛掛廍 [2] 牛犇廍 [3] 牛掛 [4] 牛犇 [5] 糖餉
[6] 行

tivators and tenants to retain more profit in their own hands, as it freed them from the need to rely on mills run by landlords or merchants. Yet this does not mean that individuals could pursue profit unconditionally to the detriment of other members. Rather the emphasis was on maximising and protecting the profit of individuals according to their investment share in the mill without ignoring the rights of other members, and without running counter to the spirit of co-operative management. If individuals wanted to expand their sugar production, they had to acquire more share units in the mill, which gave them the right to crush more sugarcane. The joint-management system clearly embodied an exclusionist attitude towards non-members. For instance, commissions for crushing outsiders' sugarcane could only be considered late in the season after all the members' cane had been processed, and then only by unanimous consent. Any members secretly accepting commissions from non-members faced fines. In short, the joint-management system did not aim to increase production through outside supplies of sugarcane, but steadfastly strove to guarantee the access of members to crushing and sugar-making facilities. This was an important consideration in a situation where the members lacked funds to set up sugar mills by themselves.

In short, the land-tenure system discouraged peasants without access to sugar mills from growing sugarcane. If merchants wanted more sugar they had to either establish mills themselves, or advance funds to peasants to set up their own.

Mill labour

All sugar millers, no matter whether tenant, owner–cultivator, landlord or merchant, had to hire some free labour to undertake skilled work during the crushing season.[a] In written contracts such workers appeared under the name *huo-chi*[1]. The *Chhih Khan Pi Than*[2] (Fort Provintia Essays) of c. +1736 enumerated

Footnotes to page 120 (*cont.*)

(3) The same situation prevails in cases of arson committed against the cane fields of mill members. The member whose cane field has been burnt has to inform the authorities of the offender's name if known, and any expenses incurred are to be shared amongst all members.

(4) Custom allows passers-by to help themselves to two or three stalks of sugarcane from the cane fields of mill members to quench their thirst, but if larger amounts are taken members are duty bound to band together, apprehend and hand the offender over to the authorities.

(5) Workers are employed by the sugar mill as a whole, and efforts should be taken to recruit honest people who know their place in society (*chheng shih shou fen chih jen*[3]). If workers break the law only the overseer on duty (*thou-chia*[4]), the member in charge of the day-to-day running of the mill that year, is to answer to the authorities.

The original document is copied in Anon (553), pp. 17–20. For further details see Daniels (*2*), pp. 79–80.

[a] See Ku Ssu-Hsieh (*1*), pp. 34b–35a for late +17th-century Kuang-Tung. Phêng Tse-I (*1*), vol. 1, pp. 266–7 gives two further instances from Kuang-Tung; one for Lo-Ting Chou[5] in +1741 where workers received payment every five days and the other for Ying-Tê[6] county in 1803.

[1] 夥記 [2] 赤嵌筆談 [3] 誠定守分之人 [4] 頭家 [5] 羅定州
[6] 英德縣

a total of seventeen workers in sugar mills; they included two sugar masters (*thang-shih*[1]), two sugar boilers (*huo-kung*[2]), two mill feeders (*chhê-kung*[3]), two cow women (*niu-pho*[4]), seven cane cutters (*po-chê*[5]), one animal feeder (*tshai-chê-wei*[6]) and one animal attendant (*khan-niu*[7]). The wages of these workers amounted to as much as sixty or seventy taels, presumably for the entire crushing period, the high level of which probably reflected the shortage of labour on Taiwan during the early +18th century.[a] Japanese surveys of the late 19th century revealed that sugar mills could be broadly classified into three sizes based on the number of workers: small-scale mills with eight workers, medium-scale mills with fourteen to twenty-four workers and large-scale ones employing eighteen to thirty-four workers. Merchants, the principal owners of large-scale mills, lacking other forms of labour, needed to employ cane cutters and transport labourers as well as skilled sugar artisans, hence the larger numbers. The medium- and small-scale mills with fewer hired workers were landlord-owned and joint-management mills.[b]

We only possess scanty information about the employment conditions of sugar-mill workers. Methods of wage payment varied from place to place; it could be according to the entire crushing season, by the month, day, bucket of cane juice extracted or amount of sugar made. Nevertheless, close analysis reveals three basic ways of remuneration: one, by time wages (*hsien-hsiao yin*[8]); two, by piece-work payment (*fen-sheng yin*[9] or *thung-shêng yin*[10]); and three, by allowances of rice, oil, tobacco, sugar, and even drink money. Most mills probably adopted a combination of all ways.

Sugar mills did not employ workers throughout the whole year, only during the crushing season which lasted for about ninety days. As mentioned above, such skilled sugar workers as sugar masters and sugar boilers travelled the sugar districts during the crushing season offering their services. Merchant-owned mills had to hire unskilled as well as skilled labour. Jointly managed mills, however, drew their unskilled labour from those with shares in the mill and from the local community (*kyōdōtai*[11]). While a market for skilled sugar workers did exist in Taiwan during the +18th and 19th centuries, it remained solely seasonal; unskilled workers, and probably many skilled ones too, returned to the ranks of the peasantry at the end of each season.

Ever fearsome of rebellion and banditry breaking out from large numbers of workers congregating together in one spot, local officials adopted measures to nip potential trouble in the bud. This was the case with the calendering trade in the cotton cloth industry in the city of Su-Chou from the Yung-Chêng[12] era

[a] *THSCL*, p. 57.
[b] Daniels (*2*), p. 87.

[1] 糖師 [2] 火工 [3] 車工 [4] 牛婆 [5] 斫蔗
[6] 採蔗尾 [7] 看牛 [8] 現銷銀 [9] 分聲銀 [10] 桶聲銀
[11] 共同體 [12] 雍正

(+1723 to +1735), to name but one instance. With 10,000 workers, mostly from outside areas, engaged in this sector of the cotton industry alone, the authorities introduced the *pao-chia*[1] system of local defence and mutual surveillance to control them.[a] During the late +17th and +18th centuries authorities also regarded sugar workers as a source of potential social disorder, as we have already seen in the earlier citation from the +1710 gazetteer for Nan-Khang county in Chiang-Hsi. Legal regulations, aimed to prevent outlaws from disguising themselves as sugar mill workers, obliged sugar millers in Taiwan and Kuang-Tung to report the names of the artisans and workers they hired to local government authorities. The Chhing dynasty continued the practice of taxing sugar mills that began in Taiwan during the Chêng period (+1661 to +1683), and required all sugar millers to apply for official permission before setting up mills. The earliest reference to this practice appeared in a land document dated +1725 which clearly stated the legal responsibilities of the sugar millers; millers were accountable for the behaviour of all hired workers, had to report their names and domiciles to the local magistrate, and pay a fee (*pu-chieh yin*[2]) for authorisation.[b] This system served a double purpose; it allowed the state to control the workers, and at the same time gain tax revenue from an important handicraft industry rather restrict sugar production.[c]

Sugar production as a rural handicraft industry

Next let us compare the organisation of sugar production on Taiwan with that of cotton and silk weaving in the Chiang-Nan region. Two characteristics are evident.

First, there is the integrated nature of sugar production which was characterised by the absence of merchant intervention in the production process. Since the same peasants undertook both the cultivation of sugarcane and the manufacture of sugar, this freed them from the need to rely on buying and selling raw materials from merchants at the various intermediate stages of production as in cotton and silk production. By the +16th and +17th centuries merchants had penetrated into almost every stage of production in the Chiang-Nan cotton industry. At the beginning, merchants had little room to move as single peasant household units managed all stages of the textile production process, but they got their foot in the door when the tasks of ginning, spinning and weaving were divided out amongst specialists; they assumed the role of middlemen in

[a] See memorial submitted to the throne in +1730 by Li Wei in Kuo Li Ku Kung Po Wu Yüan (*1*), vol 16, pp. 747–53.

[b] In Kuang-Tung the first known reference for sugar millers submitting such documents is in the prohibition, *yüng ko thang-liao lou-kuei*[3], issued by Ku Ssu-Hsieh[4], the magistrate of Hsin-Hui[5] county near Kuang-Chou, who assumed office in +1707, see Ku Ssu-Hsieh (*1*), pp. 34b–35a. For the year in which Ku took up office see the +1841 *Hsin-Hui HC*, ch. 5, *chi-kuan piao*, pp. 16a–16b.

[c] For sources and analysis see Daniels (*2*), pp. 53–4.

[1] 保甲 [2] 廍結銀 [3] 永革糖竈陋規 [4] 顧嗣協 [5] 新會縣

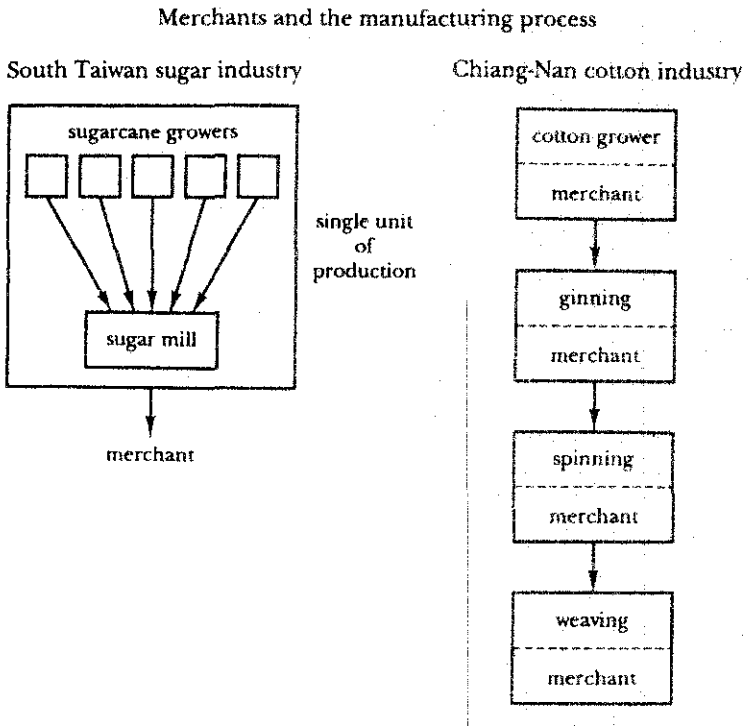


Fig. 14. Diagram showing the difference between the roles of merchants in sugar production in south Taiwan and cotton production in Chiang-Nan. Notice that merchants played no part in the agricultural and manufacturing process of sugar, while they intervened at each stage with cotton.

all the transactions between the different specialists before the cloth was finally finished. Lack of funds on the part of the peasants put merchants in an advantageous position to exercise control over them through usurious loans and other practices. The technological demands of cane growing and sugar making did not allow such a fine division of labour, and thus prevented merchants from assuming the role of middlemen between different stages in the manufacturing process. These differences are graphically illustrated in Fig. 14.[a]

Second, the integration of sugar production with a modified type of autarkic agriculture reduced the cane grower's overall dependency on the market. Cotton and silk weaving households in Chiang-Nan grew rice, but often it proved insufficient to sustain a single family for a whole year, and they had to buy rice on the market. They soon became dependent on pawnshops and other forms of usurious capital, for they had to pawn their new rice to obtain silver to pay taxes; they redeemed the rice for use as food with the income received from

[a] Similar patterns are observable in the Chiang-Nan silk industry. Whereas cane-growing peasants only dealt with merchants after the sugar was produced, the arrangement of the sericulturist not being the same person as the weaver permitted merchants to play the role of an intermediary between the different stages of production, see Sun (2), pp. 94–9.

raw silk.[a] This made spinning and weaving households extremely dependent on the vagaries of the market for obtaining their staple food. It also made them particularly vulnerable to the depredations of merchants and pawnshops. On Taiwan, on the other hand, sugar-making peasants provided a large portion of their own food needs, without relying on the market, by intercropping and rotating sugarcane with sweet potatoes, a staple food, along with peanuts and vegetables. This reduced their dependency on the market for food supplies, thus helping to shield them from market fluctuations and crop failures.[b]

The differences between the production of sugar in Taiwan and cotton and silk in Chiang-Nan arose in part from the respective technologies. While each technological process in cotton and silk manufacturing became highly specialised involving a number of different people, sugar making remained an integrated process in which the sugarcane cultivator also made the sugar. Merchant capital was kept out of the sugar-making process, and diversification amongst a number of different people was avoided because of the necessity of crushing sugarcane a short time after harvesting, before deterioration set in.[c] Merchant capital in the Chiang-Nan delta region did not stop at business transactions, but also intruded into the sphere of production. In contrast, the peculiar requirements of sugar making prevented merchants from gaining a foothold in the production process. The need to crush sugarcane and make sugar speedily after harvesting relegated merchants to the position of mere purchasers of the finished product. This allowed sugar-producing peasants to grow food crops, and enabled them to attain a certain degree of self-sufficiency in staple food, thus giving them some insurance against the fluctuations of the market economy. It is also an extremely fine example of the way in which handicraft-scale technology placed historical limitations on social and economic activities.

(iv) *Chinese sugar from 1870 to 1930*

The history of the Chinese sugar trade between 1870 and 1930 may be chronologically divided into three periods:

1 1860 to 1893, during which exports of Chinese sugar increased
2 1893 to 1900, when China changed from a net exporter of sugar to a net importer
3 1900 to 1930, which saw a continual increase in imports of foreign centrifugal sugar. This created a double tiered domestic sugar market for centrifugal sugar and native non-centrifugal sugar respectively.

[a] Oyama (1), pp. 139–42 provided an account of these practices.
[b] Daniels (1), pp. 96–7 and Daniels (2), pp. 98–101.
[c] A short time after harvesting small quantities of deleterious substances appear in sugarcane, making it harder to crystallise.

One of the main characteristics of the world sugar industry during the second half of the 19th century was the rise and development of large-scale sugar refining. In 1878 and 1884 two sugar refineries were established in Hong Kong with British capital. These two refineries, which mainly drew their supplies of raw sugar from Java and the Philippines, pioneered and fostered the centrifugal raw sugar markets in China and Japan. After 1910 Japanese refined sugar, and after 1925 Javan 'mill white' sugar, poured into the Chinese domestic market, gradually ousting Hong Kong refined sugar. Nevertheless, the market for Chinese non-centrifugal sugar persisted despite great diminishment due to increasingly large imports of foreign centrifugal sugar.

The period from 1860 to 1893 saw an increase in sugar production in China in response to rapidly growing domestic and overseas trade. Once again let us briefly examine how sugar production expanded in southern Taiwan.[a] By the 1880s Taiwan-based merchants and some guild merchants had attained firm control and, in certain areas such as Takow, even a virtual monopoly over sugar production. These merchants advanced or lent funds to peasants at usurious rates of interest for growing sugarcane and making sugar. Peasants unable to maintain solvency were forced to continue making sugar every year for the merchant in order to service their rapidly accumulating debt. Merchants therefore were able to guarantee themselves a constant and reliable supply of sugar by keeping peasants in a state of perpetual debt. They adjusted production to meet changing market demands by regulating the funds advanced to peasants.[b] Needless to say, merchants also employed other methods for extracting extra profits in the course of sugar transactions, such as utilising (1) differences in the currency exchange rate, (2) differences between nominal and actual sugar weights, and (3) retaining the power to arbitrarily fix the price of sugar grades.[c]

This type of advance payment system had been practised in Taiwan since the +18th century, but after the opening of the Treaty Ports to foreign trade it was strengthened by the establishment of financial arrangements for the new trade. The Hongkong and Shanghai Banking Corporation which serviced the triangular trade between southern Taiwan, Japan and south China began to provide finance for the sugar trade from their Amoy agency by lending Chinese merchants funds for sugar purchases, and by making advances to foreign merchants for sugar exports during the 1870s. The establishment of an agency of the Hongkong and Shanghai Banking Corporation at Tainan in 1886 ensured an even stabler supply of finance. By financing the sugar trade through a system that went down to the cane-growing peasant, this foreign banking corporation linked the rural areas of Taiwan with the international financial system.

[a] This outline of modern period is based on Daniels (3).

[b] A constant supply of sugarcane was a crucial factor for marketing. Simon Commander (Commander (1), p. 509) has shown that the advance debt nexus in India was important for ensuring a constant supply of sugarcane as in Taiwan.

[c] Daniels (1).

To maintain a steady supply of sugar to the expanding domestic and overseas markets, Chinese export merchants, particularly compradors and Taiwan-based merchants, established agencies in the sugar-producing districts to facilitate the acquisition of sugar. These agencies made loans to peasants at usurious rates of interest, and collected and transported the sugar when finally ready. This system exhibited two characteristics in relation to the peasant economy. First, it expanded sugar production without coming into conflict with the landlord system. Merchant control over sugar production only extended to loaning funds to peasants, many of them tenants, and therefore basically did not clash with the rent-collecting interests of landlords. Second, although the putting-out system encouraged the cultivation of sugarcane at the expense of other crops, such as indigo, south Taiwan never manifested a true monoculture economy because of competition from wet rice and other crops. In addition, the cultivation of subsistence crops cushioned cane-growing peasants from the predations of merchants and market fluctuations. In other words, the rapid expansion of sugar production was realised not by transforming, but by preserving the pre-modern relations of production enumerated earlier. In this we can see the adaptability of the Chinese system of sugar production and its technology, as well as its limitations.

Modern Western sugar refiners shunned Chinese non-centrifugal raw sugar because of its high molasses content. For their purposes it remained a low-grade sugar with an inferior sugar content and low commercial net, unsuitable for refining in large-scale factories. During the late 19th century the world sugar market increasingly came to require high-grade raw sugar for refining, but the reluctance of the Chinese to change their sugar manufacturing technology in order to raise the quality of their sugar (i.e. the sugar content and commercial net) prevented Chinese sugar from competing with centrifugal sugars manufactured in Java and other European colonies in Asia. Changing Chinese sugar technology was not a simple task because production, and indeed the technology itself, was geared to the needs of the pre-modern East Asian market with its traditional preference for sugar with a high molasses content. Certain districts manufactured sugars of a particular quality for specific markets. For instance, Taiwan Fu[1] and Takow[2] districts of Taiwan produced sugars of slightly different sugar content and commercial net, for the northern Chinese and Japanese markets respectively, prior to the Japanese takeover in 1895. The prices for these sugars varied according to the demands of the two markets. Any attempt to establish modern sugar mills in China would have to break through the interlaced structure of autarkic rural economy, technology, consumer preferences and market ties on which the sugar industry was founded.

The fact that China did not change the quality of its raw sugar directly stimulated the sudden drop in demand for Chinese raw sugar on the world market,

[1] 臺灣府 [2] 打狗

and was one of the major reasons for the decline of Chinese sugar exports after the 1890s. It also set the stage for the ensuing huge influx of cheaper foreign centrifugal sugar from European and Japanese colonies in Asia into the domestic market. When Chinese peasants found it unprofitable to grow sugarcane and make sugar, their response was to simply plant other crops. Once again it was their subsistence base that sheltered them to a certain extent from market forces.

The decline of native non-centrifugal sugar production in China after the 1890s stands in contrast to the experience of India where this sector has held its own until the present day.[a] The lack of government intervention and support was another factor working against the growth of a modern sugar industry in China. The effects of this can be seen in the following three areas:

1 Experimental stations for breeding new clones were not established until after the Chinese revolution of 1949.
2 Protective tariffs were not introduced until the 1930s, by which time domestic sugar production had been almost destroyed.
3 The case of India showed that the promotion of the small producer was also a viable method of encouraging sugar production, but the Chinese government took no measures in this regard.

As shall become apparent later in our story, China was the source of much of the sugar technology adopted in tropical America, but followed a completely different path of social and economic development. J. H. Galloway has postulated for tropical America that sugar production on plantations with slave labour improved greatly with the introduction of the three-roller mill, new sugarcane clones and other innovations during the +17th and +18th centuries, and that the next change came with the adoption of the central sugar mills system with concomitant amalgamation of plantations during the 19th century after emancipation.[b] China employed similar technology to that of tropical America until the early 19th century, but experienced neither large plantations, nor the brutality of slave labour. In 1949 on the eve of the revolution, there were only four modern cane-sugar factories in operation, and the central factory system really did not develop until the 1950s and later.[c] This situation arose for two reasons: first, China experienced no industrial revolution to create a market for sugar as a food of the working class and, second, the economic rationality of Chinese peasants, principally their reluctance to part with their subsistence bases, made the amalgamation of small and scattered landholdings difficult in the absence of a strong government policy.

[a] For India see Kiyokawa and Ōno (1)
[b] See Galloway (4)
[c] Tacke, Stepanov, Walker, Ali & Henning (1), vol. 1, p. 209.

(c) SUGARCANE CLONES,[a] SPECIES AND ORIGINS

(1) Sugarcane Species

As an ancient domesticated plant sugarcane emerged onto the world archaeological record about −2500 in New Guinea.[b] In historical time, Nearchus, Alexander the Great's admiral, mentioned sugarcane in India in −325, as the 'reeds that ... produce honey, although there are no bees'. In China, court officials used it to alleviate the effects of drinking alcohol by the −1st century.[c]

Sugarcane is a large grass (Gramineae) of the genus *Saccharum*, tribe Andropogoneae.[d] Humans have extensively utilised the Andropogoneae for cereals (*Sorghum*, *Zea*), fodder (*Iseilema*, *Themeda*, etc.), sugar (*Saccharum*, *Sorghum*, *Zea*), essential oils (*Cymbopogon*) and archery, thatching, house building (*Imperata*, *Miscanthus*, etc.[e]). Before outlining the origin of sugarcane it is instructive to refer to comments by Professor Johann Beckman[f] who addressed the Royal Society of Göttingen at the turn of the 18th century: '... the history of sugar has been involved, by learned men, in such a confusion of words and things foreign to it, that it costs no little time and labour to separate truth from probability'. The history of the origins and taxonomy of the sugarcanes exemplify this problem.

The genus *Saccharum* includes three species of sugarcane:[g] *Saccharum officinarum* L., the original Linnean species, *S. sinense* Roxb. (Chinese sugarcanes) and *S. barberi* Jesw. (Indian sugarcanes).[h] Their centres of origin are indicated in Fig. 16a and and general morphology summarised in Table 10. The archetypical

[a] Sugarcanes are propagated vegetatively by cuttings, and are therefore clones (genetically uniform), not varieties (section of a species and therefore not entirely genetically uniform like a clone). Sugarcane technologists have employed the terms varieties and clones interchangeably but are now urging standardisation on clones, see Daniels & Roach (2). The term cultivar (abbreviation cv.) is used for commercial clones.

[b] Bulmer (1), pp. 29–33. Sugarcane appeared about the time of the earliest datings for rice. This evidence from New Guinea was the only archaeological find for sugarcane, but it could have developed far earlier since J. Golson (Golson (2), p. 46) has evidence for agriculture in New Guinea as early as −7000.

[c] For Nearchus see Deerr's translation from Strabo (Deerr (1), p. 63), and for medicinal uses in connection with alcohol, see *NFTMC, shang*, p.5a and the *Chhien Han Shu*, ch. 22, p. 1063.

[d] See Daniels and Roach (1) for taxonomy of *Saccharum* and its close relatives. General physiology and biochemistry of *Saccharum* sp. were detailed in Alexander, A. G. (1) and Bull & Glasziou (1). J. S. Hawker gave a comparative study of sugar accumulation in plants (see Hawker (1)). For sugarcane botany see van Dillewijn (3).

[e] Hutchinson (2), p. 740.

[f] Beckman (1), p. 3.

[g] Other genera such as *Zea* and *Sorghum* have specific varieties that accumulate sucrose in their stalks, but they are not known as sugarcanes. In sugarcane literature, the genus *Saccharum* includes these three sugarcane species, two wild species *S. spontaneum* L. (tropical & temperate Mediterranean, Asia and Far East) and *S. robustum* Brandes & Jeswiet *ex* Grassl. (New Guinea and Indonesia east of the Wallace line) and *S. edule* Hassk, cultivated for its edible inflorescence. See Daniels & Roach (1), tables 6 and 7, pp. 26 and 29.

[h] These species have been accepted by the International Society of Sugarcane Technologists for their practical value in sugarcane breeding and technology. Some grass taxonomists have combined them together under *S. officinarum*, e.g. see Bor (1), p. 212. See Daniels, Roach, Daniels & Paton (1) for a recent circumscription of *S. sinense* and *S. barberi*.

Table 10. *Characteristics of* S. officinarum, S. sinense *and* S. barberi *viewed typologically (There is considerable variation within species.)*

	S. officinarum	*S. sinense*	*S. barberi*
Stalk thickness	thick, c. 30 mm	medium, c. 20 mm	thin, c. 15 mm
Stalk internodes	compressed, c. 6 cm	long, c. 15 mm	long, c. 12 cm
Leaf width	wide, c. 50 mm	medium, c. 40 mm	thin, c. 25 mm
Chromosome no. (2n)	80	115–120	90–93
Number of clones	>1000	<50	<20

Indicative dimensions based on Artschwager (1) and Artschwager & Brandes (1) have been added. For chromosome numbers see Daniels, Roach, Daniels & Paton (1). Clone numbers are rough estimates taking into account Berding and Roach (1) on *S. officinarum* collection expeditions and the circumscription of Daniels, Roach, Daniels & Paton (1) for *S. sinense* and *S. barberi*.

sugarcanes were the large, soft, thick, brightly coloured *S. officinarum* from New Guinea, which were ideally adapted to the tropics, but only grew up to 35°N with careful cultivation in sheltered gardens in China and elsewhere (see Fig. 15).[a] Though usually grown for chewing or as fruit canes, they served as the major clones for sugar manufacture by European planters in tropical colonies until the introduction of hybrid clones in the 1920s.[b] *S. sinense*, the Chinese sugarcanes, have yellow-green stalks, thinner than *S. officinarum*, and were ideally adapted to temperate zones, especially China south of the Nan-Ling ranges. *S. sinense* clones have been grown at times in temperate zones in Taiwan, Japan, Natal, Argentina and the United States. *S. barberi* clones were thinner and hardier than both *S. officinarum* and *S. sinense*, and adapted to the cold, harsh climate of northern India.

Turning to origins, many hypotheses have been advanced on the origin of sugarcane, and Daniels and Roach[c] have surveyed past, conflicting claims. The current position is that *S. officinarum* undoubtedly evolved in the New Guinea and adjacent islands east of the Wallace line, thus making New Guinea the centre of diversity.[d] *S. sinense* developed somewhere in south China, the best guess being in Yunnan and contiguous provinces, the area of distribution of the wild relative *Saccharum spontaneum* L., and other related genera. *S. barberi*, a

[a] Artschwager & Brandes (1) described over 400 clones and Brandes (1) provided a valuable introduction to the origin, evolution and dispersal of *S. officinarum*, which, though dated, contained valuable information not available elsewhere. See Daniels and Roach (1), pp. 48–66 for a review of subsequent data and hypotheses. *S. officinarum* has been recorded in gardens as far north as Korea, see Rondot (1), p. 201. Deerr (Deerr (1), p. 72) mentioned Tiflis (41°42′) and Gaeta, Italy (41° 12′) as the extreme northern extension of sugarcane. Helmut Blume (Blume (1), p. 79) wrote that modern cultivators grew commercial sugarcane as far north as 37° on the Costa del Sol, Spain. See Blume (1) for a comprehensive, modern geography of sugarcane.

[b] There are various colloquial English names for *S. officinarum*: chewing, fruit, original, noble, native, primitive, Melanesian garden canes, see Brandes (1), pp. 3–6.

[c] Daniels & Roach (1), table 12, p. 51.

[d] See Zohary (3) for a review of the concept of centres of origin versus centres of diversity, Harlan (6) on centres and non-centres, and Daniels and Roach (1) for the origin of *S. officinarum* in depth.



Fig. 15. *Saccharum officinarum* L. in a Melanesian garden in New Guinea. Sugarcane supported in this manner was available for harvest year round (photographed on the 1914 CSR Limited of Australia sugarcane collecting expedition).

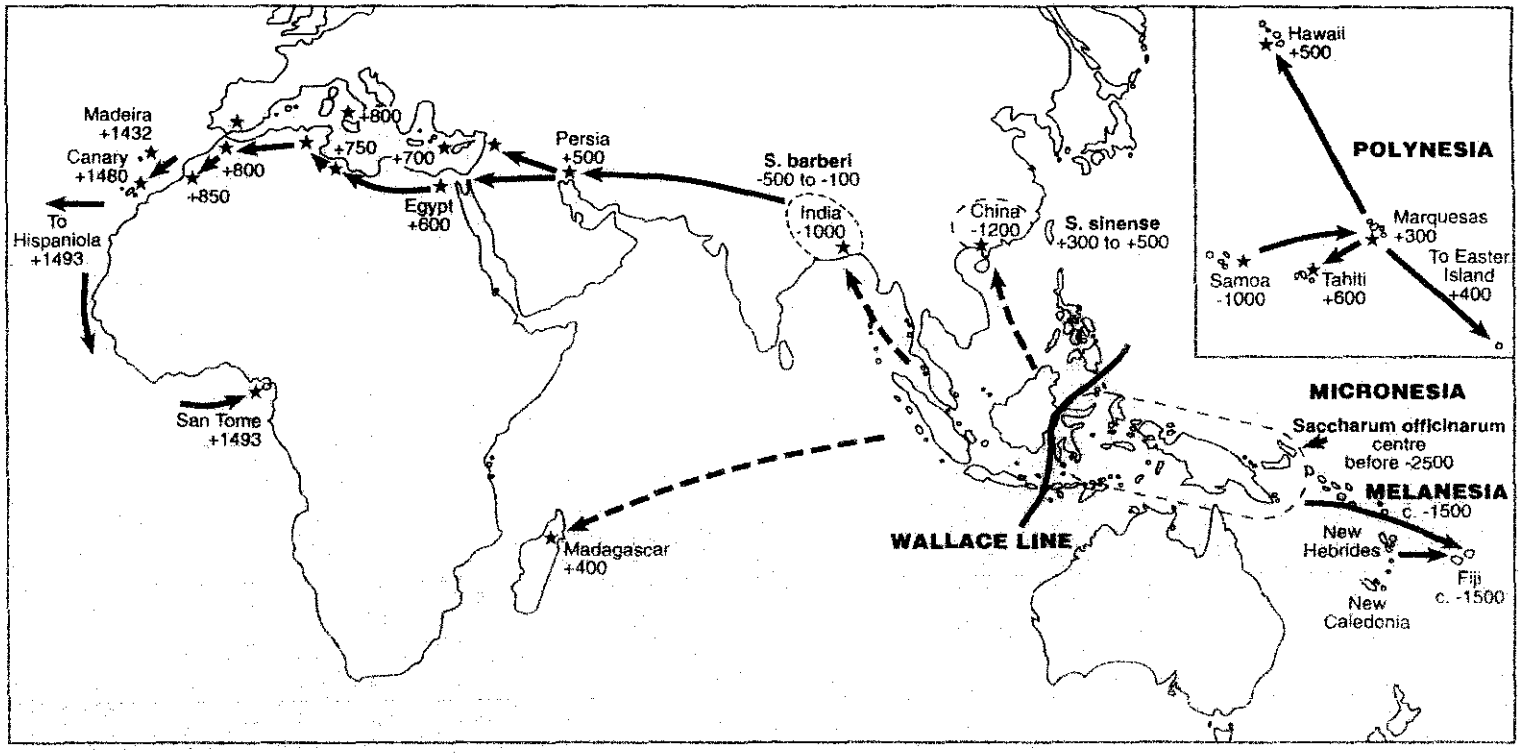


Fig. 16a. Map showing centres of origin of *S. officinarum* in New Guinea and islands east of the Wallace line; *S. sinense* in China (Yunnan and contiguous provinces) and *S. barberi* in India (Bihar, Bengal and Orissa). The centre of origin of *S. officinarum* was in Wallacea/New Guinea prior to −2500, the date it was found in an archaeological site, see Bulmer (1). It was a primary Austronesian cultigen (Blust (1)), and dispersed with the Austronesians to eastern Melanesia after −1500 and to eastern Polynesia after −1000 (datings simplified from Jennings (1), see also White and Allen (1), Spriggs (1) and Tryon (1)). To the west *S. officinarum* appeared in the Indian text, the *Artharva Veda* about −1000 (Daniels and Daniels (1)) and archaic Chinese about −1200 (Benedict (2), p. 324). Datings for *S. barberi* and *S. sinense*, −1000 to −500 and +300 to +500, respectively (Daniels and Daniels (1)). Spread from Persia to North Africa, Morocco by the Arabs simplified from Lombard (1). Datings to the Atlantic and New World from Deerr (1), pp. 100, 102, 116. Dating to Madagascar from Dahl (1), pp. 366–9.

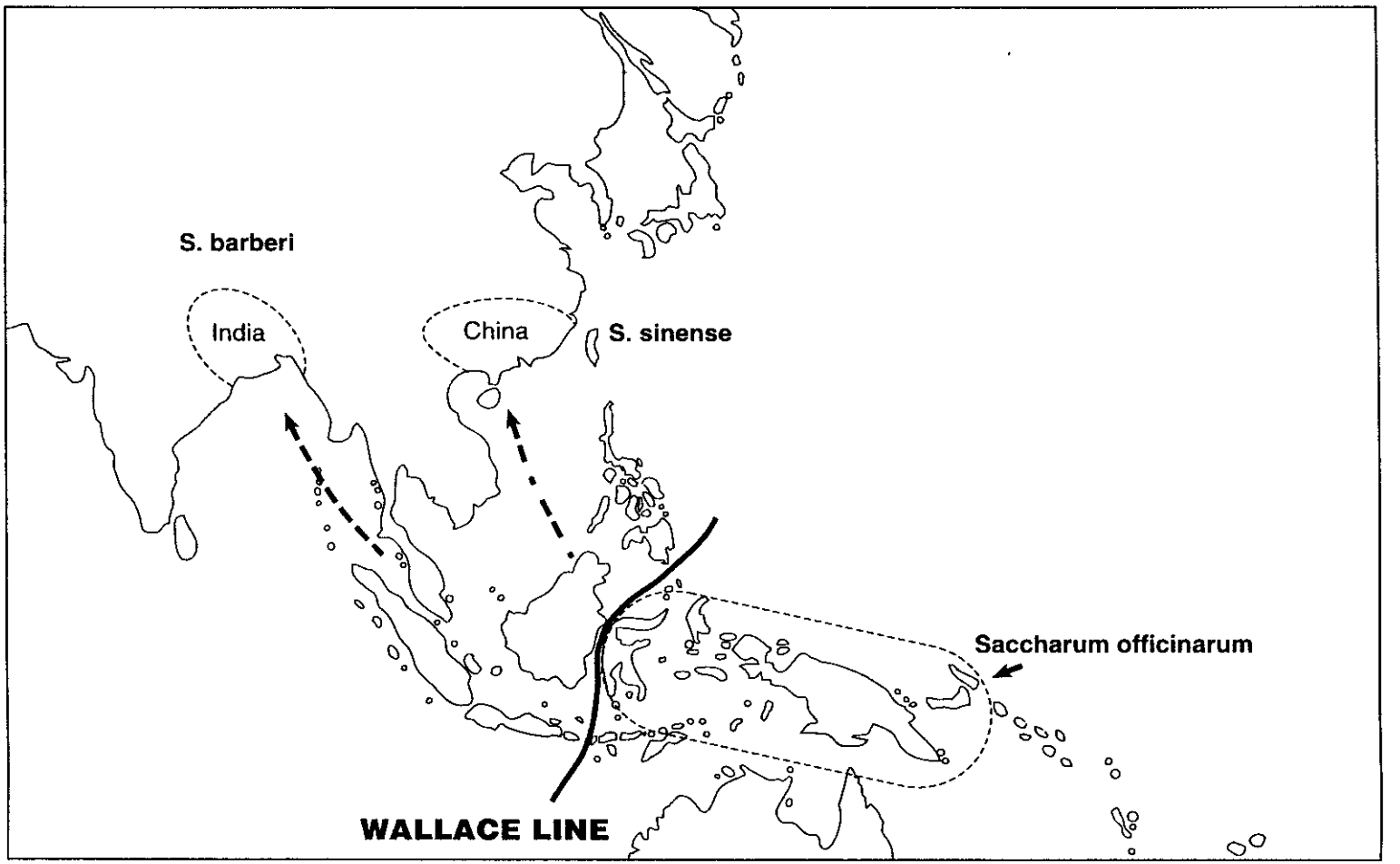


Fig. 16*b*. Map of the Brandes hypothesis on the dispersal of *Saccharum officinarum* L. as adapted by Daniels and Roach (1), p. 69.

native of North India,[a] was grown in the foothills of the Himalayas from Bengal to the Punjab; it consisted of a number of horticultural groups adapted to various environments. Researchers have not been able to establish clear centres of diversity for *S. sinense* and *S. barberi*.

Few scholars would dispute these statements, but unanimity rapidly disappears when we turn to the issue of whether these species developed independently or not. Until quite recently, what we have called the Brandes hypothesis, see Fig. 16b, has been generally accepted. It envisaged that *S. officinarum* evolved in New Guinea, and about −1500 dispersed south from there, into island Melanesia and Polynesia with Austronesian migrations. To the north, it appeared in India in the *Atharva-Veda* which was written about −1000.[b] For China, the dispersal evidence remained linguistic. Benedict has traced roots for sugarcane in Thai and Kadai languages of the Yüeh peoples of the south China coast and their transfer into archaic Chinese about −1200.[c] These dates indicated a move north from the centre of origin in New Guinea well prior to −1000. Daniels & Daniels (see Daniels & Daniels (1)) accepted these datings as evidence of the primacy of sugarcane *S. officinarum* in Asia; if *S. sinense* and *S. barberi* arose from indigenous taxa, they merely indicated the recognition of these species in the cultural record. In India and China, *S. officinarum* (Fig. 17) introgressed with wild canes to produce the Indian and Chinese sugarcanes.[d] Jeswiet raised these groups to species status, *Saccharum barberi* Jesw and *Saccharum sinense* Roxb. respectively in 1925.[e]

These 'hybrid' species extended the range of commercial sugarcane growing in pre-modern Asia from about 25°N to 35°N. They are readily distinguished from *S. officinarum* by chromosome number, thinner stalks and leaves, and *S. officinarum* clones often have brightly coloured stalks, lacking in the other two

[a] See Parthasarathy (1), p. 146 for a discussion of the possible area of introgression between *S. officinarum* and *S. spontaneum* in India to produce *S. barberi* under the Brandes hypothesis. He concluded that the 20–24°N longitude region of Bihar, Bengal and Orissa was the most likely area.

[b] Sugarcane has not been recorded in archaeological sites in India (Hutchinson (3)) although wild *Saccharum* has (Vishnu-Mittre (1), p. 26). It is not present in the earliest literature, the *Rg Veda*, of about −1500 and is only recorded at about −1000 in the *Atharva-Veda* (see Daniels and Daniels (1), p. 7). The *Atharva-Veda* was composed when the Aryans had expanded from north-west India to Bengal, see Chaitanya (1), p. 33. Therefore the *Atharva-Veda* could indicate the recognition of an existing cultigen present in pre-Aryan Bengal rather than the time of introduction to India. Sugar and sugarcane were widely mentioned in the subsequent Buddhist literature from c. −500, see Daniels and Daniels (2), pp. 36–8.

[c] See Benedict (3), p. 324. There has been some criticism of Benedict's approach, see Bellwood (1), pp. 88, 123; Pulleyblank (1), p. 436; however, sugarcane was undoubtedly a Yüeh cultigen.

[d] See Brandes (1), p. 19. This was an oversimplification, see Daniels & Roach (1), pp. 66–9 for more detail; some elements of *S. barberi* were thought to have evolved independently from *S. officinarum*.

[e] Jeswiet (1), Jeswiet had the benefit of the researches of Barber (2) and (3) on the Indian canes for his review. Barber detected five horticultural groups one of which, Pansahi, Jeswiet recognised as being synonymous with the Chinese species of Roxburgh. W. Roxburgh coined the name *Saccharum sinense* in vol. 3 of his *Plants of the Coast of Coromandel* the publication of which was completed in 1819 (Roxburgh (1), pp. 26–7, pl. 232). The Latin usage was corrected to *Saccharum sinensis* in the three editions of his *Flora Indica* of 1820, 1832 and 1874; however the original name must stand under the International Botanical Rules. Other invalid synonyms include *Saccharum chinensis* (Nees in Hooker & Arnott (1), p. 241), *Saccharum aegyptiacum* var. *sinense* Anderss., *Saccharum sinense* (Roxb.) Jeswiet and the horticultural group Sinense of Grassl (1).

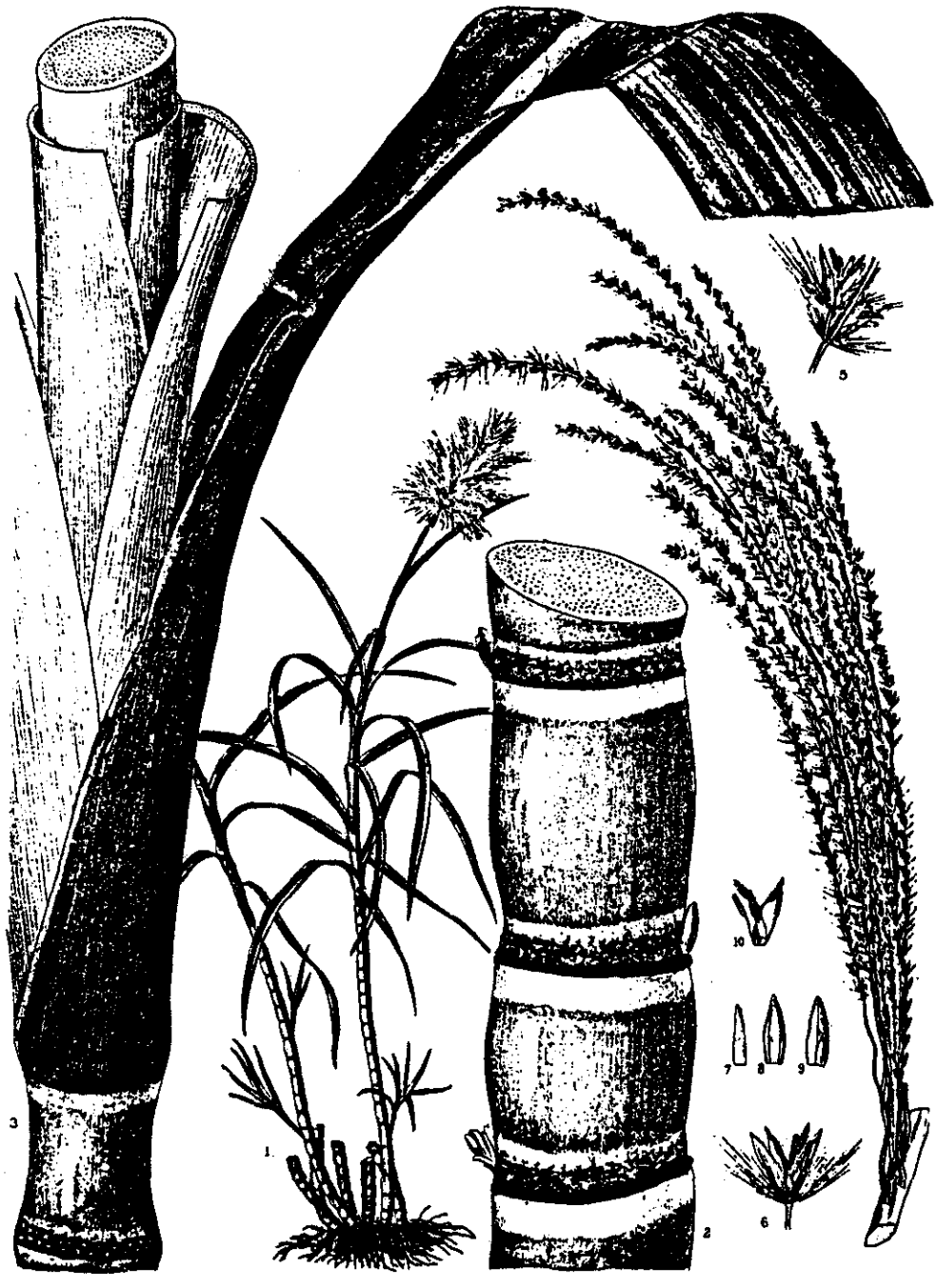


Fig. 17. A botanical drawing of *Saccharum officinarum* L. from Bentley & Trimen (1), vol. 4, pl. following p. 298. Note the large stalk diameter and solid storage tissue in stalk where sugar accumulates.

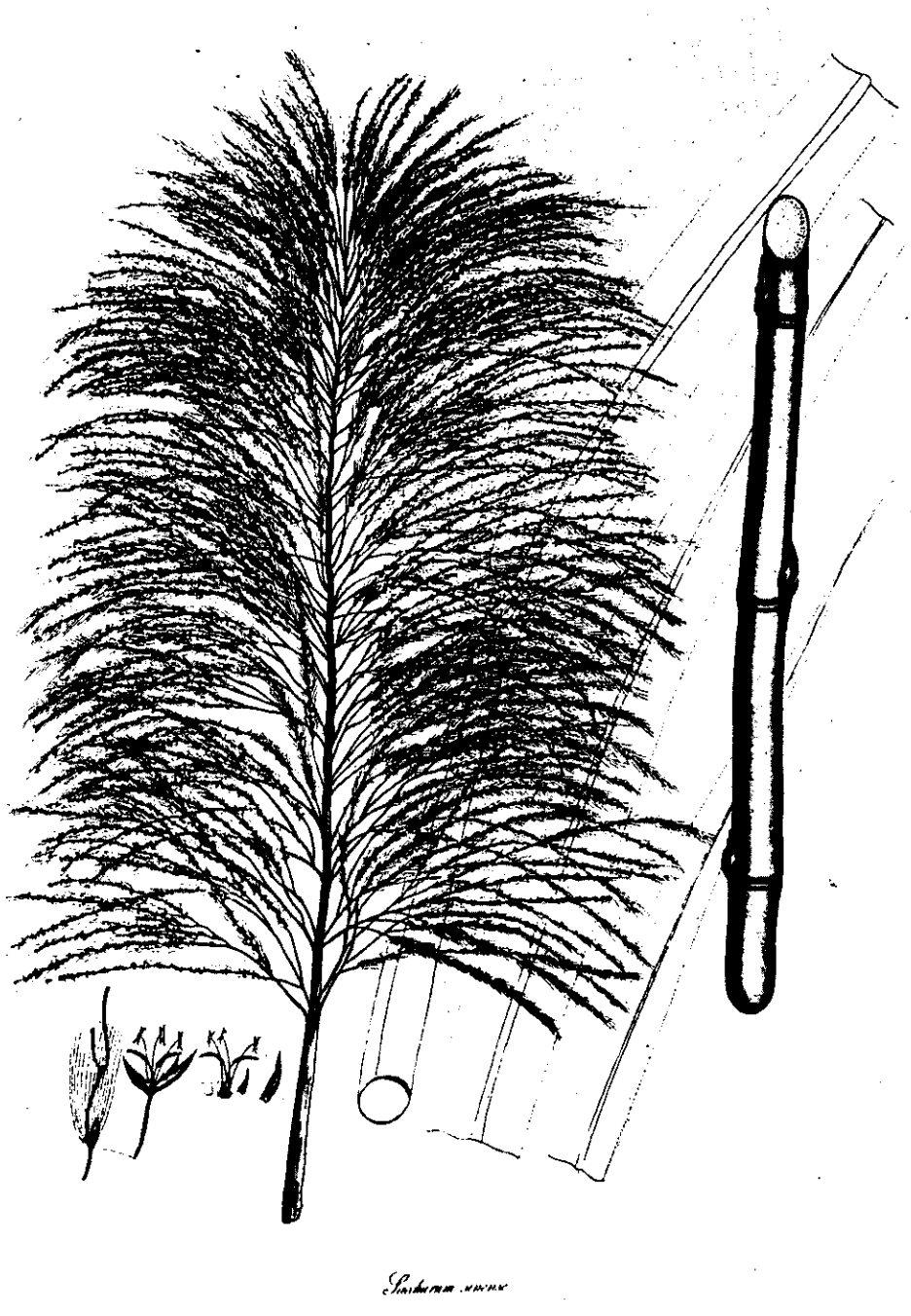


Fig. 18. This plate of *Saccharum sinense* Roxb. was appended to the original description of *S. sinense* in Roxburgh (1), vol. 3, pl. 232. A copy of the original drawing is in the Kew Herbarium. Note that it has thinner stalks than *Saccharum officinarum* L. and an ovate inflorescence.



Fig. 19. *Saccharum barberi* Jesw. (clone Katha). A photograph of field in early 20th-century India. Note the characteristic very thin reed-like stalks and narrow leaves; from Barber (1), pl. 3 lower.

species. *S. sinense* stalks are white to yellow to light green or pale purple.[a] See Table 10 for the general characteristics of the three species, Fig. 18 for an illustration of *S. sinense* and Fig. 19 for *S. barberi*. This orthodoxy has been recently challenged for both taxa. Chinese researchers have stated categorically that *S. sinense* evolved independently in China,[b] and a minority of technologists have always believed that some elements of the Indian sugarcanes rose independently in north India[c]. The crux of the controversy centres on whether *S. officinarum* was the primary sugarcane from which the other two taxa evolved.

The primacy of *S. officinarum* rests on a set of seemingly logical propositions. First, *S. officinarum* evolved in New Guinea from a closely related wild relative *Saccharum robustum* Brandes and Jeswiet *ex* Grassl. Second, some groups of *S. robustum* have thick, brightly coloured stalks resembling vigorous *S. officinarum*,

[a] The colour of *S. sinense* stalks is basically light yellow/green. The colour is modified by the thickness of a wax layer on the outside of the rind. The thickness of the wax layer combined with minor stalk colour variation can modify the overall colour to white or a pale purple. See descriptions of *S. sinense* clones in Deerr (2), p. 59 and pl. 10 (which shows the pale purple colour), Rosenfeld (1), pp. 148–64, Earle (1), pp. 83–6, 104–7, 108, Artschwager (2), Pansahi group, *passim*.

[b] Huang & Liu (1), Zhou (1).

[c] Daniels & Roach (1), table 12, p. 51.

but lacking in commercial sugar content. *S. officinarum* plausibly could have been selected from *S. robustum* populations and improved by further selection.[a] This hypothesis gained further strength from the study of Price,[b] who counted the chromosome number of the type clone of *S. robustum*, NG28–251 and found it identical to *S. officinarum*, 2n = 80. Third, in contrast, there were no known wild relatives in China and India from which *S. sinense* and *S. barberi* could have been selected directly. The only wild *Saccharum*, *S. spontaneum*, was too far removed genetically to be directly involved. Fourth, when Bremer[c] conducted a cytological examination of sugarcane during the 1920s he found that *S. officinarum* had 2n = 80 chromosomes, while *S. sinense* and *S. barberi* had c. 2n = 116 and c. 2n = 92–107 chromosomes, respectively. On face value, *S. officinarum* appeared the least complicated and looked primary. Bremer[d] also discovered that when he hybridised *S. officinarum* (2n = 80) with *S. spontaneum* (say 2n = 80),[e] there was no reduction division in *S. officinarum* and the hybrids had 2n = 120 (80 + 40) rather than the expected 2n = 80 (40 + 40). Parthasarathy[f] and Brandes[g] drew the obvious conclusion that the higher chromosome numbers of *S. sinense* and *S. barberi* resulted from this phenomenon of unreduced female gametes. I conclude that the Brandes hypothesis has a logic and any contender must provide convincing data.

As mentioned earlier, China has recently been promoted again as the centre of origin of sugarcane and sugarcane agriculture. George Richardson Porter[h] proposed this concept as early as 1830, but later scholars discarded it after the investigations of Carl Ritter of 1841 and Alphonse de Candolle of 1884 who proposed origins in India/South-East Asia.[i] Chinese researchers Huang & Liu and Zhou have independently revived the hypothesis of a Chinese origin. It appeared in some Western literature written by Chinese authors.[j] This claim has been examined in Daniels, Paton, Smith & Roach (1) and Daniels & Daniels (5) where it is suggested that the Chinese researchers gained credence from the investigations of Robert Blust, a linguist, and Peter Bellwood, a pre-historian.[k] Blust presented linguistic data to show that sugarcane was one of the original Austronesian cultigens, and Bellwood included it as one of the cultigens in his

[a] Brandes (1), p. 27.
[b] Price (1).
[c] Bremer (2).
[d] Bremer (1).
[e] *S. spontaneum* is a polyploid series from 2n = 40–128, Panje & Babu (1).
[f] Parthasarathy (1).
[g] Brandes (1), p. 19.
[h] Porter (1) p. 9.
[i] An India/South-East-Asian origin was proposed by Ritter (Ritter (1), pp. 320–3) as a major centre of origin. De Candolle (Candolle (1), pp. 154–60) discussed the work of Ritter and subsequent authors and came to the conclusion that 'its primitive range extended from Bengal to Cochin China' (p. 159). This statement was widely cited, and the Japanese economic historian of China, Katō Shigeshi, agreed with the thory of an Indian/Indo-China origin and subsequent dispersal to south China via Vietnam and Kuang-Tung. Katō Shigeshi (Katō (4) p. 683) dated such an introduction as occurring from the late Warring States period (–480 to –221). See Mukherjee (1) and Daniels, Smith & Paton (2) for recent scientific discussion on an Indian origin.
[j] For example, Yu, Youtai (1), p. 219.
[k] See Blust (1), (2) and Bellwood (2), (3) and (4).

scenario of Austronesian expansion. They placed the Austronesian homeland in Taiwan with a probable preceding transfer from south China. The Austronesians migrated from Taiwan to the Philippines, Indonesia, New Guinea, and from thence into the Pacific. This gave sugarcane a dating prior to −6000, and made China a candidate for primacy amongst sugarcanes. Such an early dating would make it highly unlikely that *S. officinarum* could have evolved in New Guinea, been transported to China and been ready for the Austronesian expansion. If sugarcane was ready for the Austronesian expansion, it would be more likely to have been from an indigenous *S. sinense*. Daniels & Daniels have pointed out that this hypothesis was their own inference; neither Blust nor Bellwood have commented on the origin of sugarcane.[a]

Zhou was the only Chinese scholar to present any scientific evidence on the primacy of *S. sinense*. In Daniels & Daniels (6) the inconclusive nature of his data was demonstrated, but it was concluded that the current dogma on the primacy of *S. officinarum* should be examined afresh. In the early 20th century, the most commonly accepted theory held that the Katha group of Indian canes, *S. barberi*, was the most primitive and there was a clear line of descent through gradually thicker groups to *S. officinarum*.[b] However, as mentioned earlier, this concept went into disrepute after Bremer showed that *S. officinarum* had the lowest chromosome number (2n = 80), for how could sugarcanes such as *S. sinense* and *S. barberi* be basic when they had higher chromosome numbers?[c] Daniels & Roach[d] have suggested a mechanism that can be applied in this situation. The orthodox theory holds that *S. officinarum* evolved from *S. robustum*, a product of complex introgression of related wild species on mud flats of rivers in Indonesia/New Guinea. Tests have shown that these *S. robustum* populations were not a uniform 2n = 80 chromosomes as first suggested, but displayed high variability in chromosome number, ranging from 2n = < 100 to c. 2n = 60. On these mud flats, a generation of seedlings arose every year, with univalent and mutivalent chromosome associations at meiosis, which caused chromosomes to be eliminated at random. There was a general chromosome loss with each generation and at the point of 2n = 80, the *S. officinarum* level, some combinations are sweeter and are retrieved as *S. officinarum*. As an alternative hypothesis, Daniels & Daniels ((6)) suggested that Austronesian immigrants from the south China/Taiwan area could have introduced *S. sinense* into these large grass ecosystems, thus providing a mechanism of how a c. 2n = 116 chromosome *S. sinense* could have contributed to 2n = 80 chromosome *S. officinarum*.

Having shown the feasibility of the idea that *S. sinense* could be primary, is there any other reason to believe the hypothesis valid? The answer is that we

[a] Daniels & Daniels (6). William Meacham has also helped provide a climate for these speculators as he considered that sugarcane, amongst other plants, was domesticated in lower China–Vietnam during the late Bacsonian (c. −6000), (Meacham (3), p. 158). Nevertheless, he did remark, 'many of these innovations have yet to be fully documented'.

[b] Barber (4), pp. 133–40.

[c] Bremer (1) and (2).

[d] Daniels & Roach (1), p. 64.

lack definitive information, but a few facts from biological marker studies indicate a close relationship between *S. officinarum* and *S. sinense*, and either one could have been the progenitor of the other. This included action spectra as advanced by Zhou,[a] leaf flavonoid data from Daniels *et al.*,[b] β-amylase data from Daniels *et al.*[c] and molecular genetic data from Glaszmann.[d] In each case a small sample of one or two clones of *S. sinense* were compared with a larger number of *S. officinarum* clones and therefore results have to be treated cautiously, but these studies indicated great genetic similarity between *S. sinense* and *S. officinarum*. Even more promising was the case of leaf flavonoid, 7GG.[e] 7GG was found in all 74 clones of *S. officinarum* examined, but was absent or at a very low level in *S. spontaneum*, and related genera, *Miscanthus* and *Erianthus*, in New Guinea. It registered a strong presence in *S. sinense* and *Miscanthus* in the area of origin of *S. sinense*, suggesting an introduction to New Guinea of *S. sinense* or a red-leafed *Miscanthus* used in medicine, from China. The implications were explored in Daniels *et al.*[f] and, in total, these data indicated that the alternative hypothesis of the primacy of *S. sinense* must be seriously considered. However, the proponents must provide more definitive evidence, and in particular must address this question: if *S. officinarum* was not involved in *S. sinense*, how did it evolve?

For India, Daniels & Roach[g] have formalised a long-standing minor hypothesis that *S. barberi* arose independently to *S. officinarum*. If researchers can confirm the great time depth of 6,000 years for *S. sinense*, we should keep an open mind on its possible influence in *S. barberi* evolution.

From the viewpoint of practical agriculture, the origin of individual species remains only of theoretical interest, for our major concern lies with clones of cold resistance, high sucrose content and yield, adapted to the climates of China north and south of the Nan-Ling[i] ranges.

(2) Selecting Clones for the Temperate Climate in Central China

The first sugarcane expert of Imperial India, C. A. Barber, summed up the problems of growing *S. officinarum* in northern temperate climates at the start of his sugarcane breeding career in 1915:[h]

[a] Zhou (1) cites action spectra data from Alexander and Biddulph (1).
[b] Daniels, Paton, Smith & Roach (1).
[c] Daniels, Waldron & Roach (1).
[d] See Glaszmann, Lu & Lanaud (1) in which ribosomal DNA, restriction fragment length polymorphism (RFLP) is used, to compare clones.
[e] Daniels, Paton, Smith & Roach (1), p. 12.
[f] *Ibid.*
[g] See Daniels & Roach (1), pp. 67–8.
[h] Barber (5), p. 214.

[i] 南嶺

Thick, tropical canes, the relics of successive importations, are everywhere met with. But it is generally found that these thick canes have not time to mature in the north during the hot moist period. They sometimes grow surprisingly well and are full of juice, but the ripening process by which the glucose[a] is changed to crystallisable sugar is arrested and, although extensively used as fruit and eaten raw, these exotic canes are generally useless for the manufacture of sugar.

Prior to the advent of *S. barberi* and *S. sinense*, in north India and central China respectively, it was not possible to manufacture crystal sugar on a regular basis. Glucose and fructose, in high concentration in the juice, will not allow sucrose to crystallise. This principle is utilised in the production of modern heavy 'golden syrups' of the grocery trade.

The advent of *S. sinense* proved vital for the extension of sugarcane agriculture into central China. North and south of the Nan-Ling ranges, inhabitants used *S. officinarum* for chewing, and the higher reducing sugars probably added to the flavour.

(3) Sugarcane Species in the Period −200 to +670

Chinese poets and administrators reached the land of the *Pai Yüeh*[1] or hundred Yüeh in the south around −200 and learnt of sugarcane for the first time. They transliterated the spoken word of the Yüeh peoples for sugarcane in various ways, and it should be remembered that these officials were mostly poets looking for rhymes, not technologists defining clones and species. In the following discussion, I have added bold superscripts to the romanised characters *chê*, *chu* and *kan* to make the English text more comprehensible. There are three Chinese characters romanised *chê*, two *chu* and three *kan*, see Table 11. The earliest known character for sugarcane, *chê*[1,2], originally meant a thorny bush about fifteen feet high, whose leaves can be used in place of mulberry leaves, for silk production. This character appeared in the compound word *chê*[1] *chiang*[3], sugarcane syrup, in a poem the *Chao Hun*[4] (Summons of the Soul) by Sung Yü[5], included in the *Chhu Tzhu*[6] of −240:[b]

> Stewed turtle and roast lamb,
> Served up with syrups from sugarcane

David Hawkes in his rendition of this poem interpreted *chê*[1] *chiang*[3] as meaning yam sauce.[c] However, the commentary by the +2nd-century scholar, Wang I[7],

[a] An old usage, actually glucose and fructose are involved, usually 50% of each. They are commonly known as either reducing sugars, invert sugars or fruit sugars, see Lyle (1) section 71, pp. 90–1.

[b] Tr. Liu Wu-Chi (1), p. 30.

[c] Hawkes (1), p. 107.

[1] 百越 or 百粵 [2] 柘 [3] 柘漿 [4] 招魂 [5] 宋玉
[6] 楚辭 [7] 王逸

Table 11. *Romanisation of principal characters used for sugarcane prior to +530*

(Bold superscripts have been added to make the English text more comprehensible. All characters have a small seal character unless otherwise noted.)

1. Characters which of themselves mean sugarcane		
Romanisation	Character	Explanation
chê[1]	柘	the earliest known character for sugarcane, first appeared with this meaning in a poem *Chao Hun* (Summons of the Soul) in the *Chhu Tzhu* (Songs of the South) in c. −241 and in the *Chhien Han Shu*, ch. 22, p. 1063
chê[2]	蔗	the usual character for sugarcane; from the time of the *Shuo Wên Chieh Tzu* (p. 18) of +121 all sugarcanes of whatever species were distinguished by having *chê*[2] as part of their name
chê[3]	藉	variant of *chê*[2], identical in sound and meaning, no small seal character, see Ting Fu-Pao (*1*), pp. 2–577
chu[2]	藷	rare character for sugarcane, first appeared in *Shuo Wên Chieh Tzu* (p. 18) of +121
2. Characters which do not by themselves mean sugarcane, but when used with another character meaning sugarcane, usually *chê*[2], form a 'binomial' denoting sugarcane		
Romanisation	Character	Explanation
chu[1]	諸	first appeared in a compound denoting sugarcane in Ssu-Ma Hsiang-Ju's *Tsu Hsu Fu*, −2nd century, see *Wên Hsüan* ch. 7, p. 26a
kan[1]	甘	means sweet, first appeared in a compound denoting sugarcane in *Nan Fang Tshao Mu Chuang* of +304, *shang*, p. 4b.
kan[2]	干	means pole, first appeared in *Nan Fang Tshao Mu Chuang*, of +304, *shang*, p. 5a.
kan[3]	竿	means bamboo pole, see Ting Fu-Pao (*1*), pp. 2–576

equated *chê*[1,1], with *chu*[2] *chê*[2,2], the common contemporary term for sugarcane and most scholars have accepted this interpretation.[a]

The next reference to sugarcane appeared in the poetry of Ssu-Ma Hsiang-Ju[3], who lived from approximately −179 to −117. In his *Lo Ko*[4] (Song of Happiness), we find: 'The *Thai-Tsun*[5] [an official] uses sugarcane syrup (*che*[2] *chiang*[6])

[a] For the commentary of Wang I see Tai (*1*), p. 6. and for a general discussion of this problem see Mazumdar (1), p. 38.

[1] 柘 [2] 藷蔗 [3] 司馬相如 [4] 樂歌 [5] 太尊
[6] 蔗漿

to alleviate the effects of drinking at court.'[a] In addition, Ssu-Ma Hsiang-Ju in his *Tzu Hsü Fu*[1] (Poems on Nothing), recorded sugarcane (*chu*[2] *chê*[1,2]) as one of the plants growing to the east of Yün-Meng-Tse[3], one of the seven swamps of the state of Chhu[4], south of present-day An-Lu county[5] in Ho-Pei province (approximately 31°N). The commentary by Chang I[6] stated, '*chu*[1] *chê*[2,7] is *kan*[1] *chê*[1,8]'.[b] Hsü Shen[9] equated the major existing term *chê*[2,10], with *chu*[2] *chê*[2,11] in his famous dictionary of +121, *Shuo Wên Chieh Tzu*,[12,c] and Hsi Han[13] wrote of *chu*[2] *chê*[2,11] in his *Nan Fang Tshao Mu Chuang*[14] of +304 as follows:[d]

Sugarcane, *chu*[1] *chê*[2,7], is also called *kan*[1] *chê*[2,15]. The ones grown in Chiao-Chih[16] have [stalks] several *tshun*[17] [approx. 5–7cm] in circumference and over one *chang*[18] [approx. 2.3m] high which greatly resemble bamboo. When broken and eaten they are very sweet ... Southerners say that *kan*[1] *chê*[2,15] can alleviate the effects of wine, and it is also called *kan*[2] *chê*[2,19] ... In the sixth year of the Thai-Khang period[20] (+283) the country of Fu-Nan[21] presented to the court *chu*[1] *chê*[2,7] which had three nodes (*chieh*[22]) every *chang*[18] [approx. 2.3m].

The sugarcane in this text has usually been identified as *S. officinarum*. On the basis that Hsi Han described a thick stalked sugarcane. However, as he referred to the circumference of stalks, rather than the diameter,[e] the cane could have been *S. sinense*. Nevertheless, at the same time we must recognise *S. officinarum* in the garbled reports of large sugarcanes from Fu-Nan. We will return to this point shortly.

In Volume 6, part 1 Chinese taxonomy was discussed at the genus and species level: 'But already in the +12th century the Chinese had been clear that there was no such thing as *chu*[23] (Bambusa) or *chü*[24] (Citrus) *tout court*, except perhaps as

[a] Quoted in the *NFTMC*, *shang*, p. 5a.

[b] *Wên Hsüan* ch. 7, p. 26a. Also see Tai (*1*), pp. 7–8.

[c] *Shuo Wên Chieh Tzu*, p. 18.

[d] *NFTMC*, *shang*, pp. 4b–5a. See Vol. 6, pt 1, pp. 447ff for a discussion of the authenticity of the *NFTMC*. There was an earlier description of *Kan*[1]*Chê*[2,15] in the *I Wu Chih*[25], of +90. the wording of which greatly resembled the passage translated above. It read: 'Places both far and near have sugarcane. The sugarcane produced in Chiao-Chih is especially excellent. The flavour is the same the whole stalk through. It is a few *tshun* [5–7 cm] in circumference, more than one *chang* [2.3 m] in height and is somewhat like bamboo. If broken and eaten it is found to be sweet.' (Quoted in *CMYS* 92/25/3.) The tall thick canes grown in the region extending over present-day Vietnam and Cambodia were also known to the Chinese by the names *Chiao-Chih chê*[2,26] and *Fu-Nan chê*[2,27]. See the *Shih Lin Kuang Chi* ch. 14, p. 9a for *chiao-chih che*[2,26]. The *Shih Shuo*[28] of Liu I-Chhing[29] (+403 to +444) described the latter sugarcane in the following manner. 'Fu-Nan sugarcane has three internodes per *chang* [2.45 m, clearly a gross exaggeration or a mistake], wilts under full sunlight (*chien jih chi hsiao*[30]), and breaks when blown by the wind' (quoted in *Yüan Chien Lei Han* ch. 404, p. 5a. (This passage was not included in the *Shih Shuo Hsin Yü*.)

[e] Circumference = *pi* (3.142) × diameter, therefore about 5 cm in circumference was not a very big diameter (i.e. thickness).

[1] 子虛賦 [2] 諸柘 [3] 雲夢澤 [4] 楚 [5] 安陸縣
[6] 張揖 [7] 諸蔗 [8] 甘柘 [9] 許愼 [10] 蔗
[11] 諸蔗 [12] 說文解字 [13] 嵇含 [14] 南方草木狀 [15] 甘蔗
[16] 交趾 [17] 寸 [18] 丈 [19] 干蔗 [20] 泰康
[21] 扶南國 [22] 節 [23] 竹 [24] 橘 [25] 異物志
[26] 交趾蔗 [27] 扶南蔗 [28] 世說 [29] 劉義慶 [30] 見日即消

an abstraction; one had to specify what *chu* or *chü* one was talking about by denoting it by a name of up to four syllables which almost always included the character for the genus.'[a] From the time of the *Shuo Wên Chieh Tzu* of +121 all sugarcanes of whatever species were distinguished by having *chê*[2] as part of their name.[b]

Further new 'binomials' appeared by +300 including a variety of compounds such as *kan*[2] *chê*[2,1] (recorded by Hsi Han above) and *kan*[3] *chê*[2,2]. Each combination was prefixed with the character pronounced *kan* which explained the appearance of the variety: *kan*[1] (sweet), *kan*[2] (pole), *kan*[3] (bamboo pole) and *kan*[5] (an unidentified grass). Daniels & Daniels have suggested that this diversification of terms showed that the Chinese had linguistically recognised a different, thinner sugarcane than thick *S. officinarum* and indicated the development of *S. sinense*.[c] However, this hypothesis appears to read into the data the Brandes hypothesis of *S. sinense* being derived from *S. officinarum*. It seems equally likely that various types of sugarcane (*chê*[2]) were distinguished locally by more precise terms for the first time. There are no actual clone descriptions and the experience of Japanese researchers in identifying modern collections indicated caution in allocating names to species. Akira Moriya,[d] examined a collection of sugarcane clones from the Sino-Japanese area in the 1940s, and confessed 'many intermediate types can be seen, and it is difficult to separate *S. sinense* from *S. officinarum*, especially in never-tasseling varieties.' Moriya had to resort to counting chromosome numbers and dimensions of stomata to separate the species. In addition, the effects of environment must have also confused the situation, a clone was thicker on better soil than on poorer soil. Observers evidently could not distinguish species in the period −200 to −670. Any efforts to read species into the terms given above is unwarranted at the present stage of knowledge. This was borne out in Chia Ssu-Hsieh's *Chhi Min Yao Shu* of c. +530 which equated most of the existing terms *chu*[2] *chê*[2,4], *kan*[1] *chê*[2,5], *kan chê*[2,6], *kan*[2] *chê*[2,7], *han chê*[3,8], *tu chê*[2,9]. We have to wait until Mêng Shên[10]'s *Shih Liao Pên Tshao*[11] of c. +670, before *S. officinarum* was unequivocally distinguished from *S. sinense* on the basis of the red-black stalks of the clone *khun-lun chê*[2,12]; all *S. sinense* clones were yellow to green. Even here, we must not read too

[a] Vol. 6, pt 1, p. 358.

[b] There were a few very rare minor exceptions, e.g. *chu*[1] *chê*[1]. Yet interestingly enough John Chalmers in his English and Cantonese dictionary of 1859 gave the single character *chê*[2,13] as the generic name for sugarcane, see Chalmers J. (1), p. 137. In the greatly revised and expanded version of 1907, we find compound words containing the character *chê*[2] with a qualifying prefix: *thieh chê*[2,14] (*t'it chê*[2]) which was described as 'a dark brown sugarcane' and bamboo cane, *chu*[3]*chê*[2,15] (*chunk chê*[2]) which was reported as 'a small sugar-cane, see Chalmers J. (2), p. 503.

[c] See Daniels & Daniels (1).

[d] Moriya (1), p. 161.

[1] 干蔗 [2] 竿蔗 [3] 竿 [4] 諸蔗 [5] 甘蔗
[6] 竿蔗 [7] 干蔗 [8] 邯諸 [9] 都蔗 [10] 孟詵
[11] 食療本草 [12] 崑崙蔗 [13] 蔗 [14] 鐵蔗 [15] 竹蔗

much into this statement, Mêng Shên probably just distinguished another *chê*[2] (sugarcane) by its outstanding attribute red-black stalks. I conclude that *S. officinarum* was probably available earlier, first as a green cane, which might have been one of those described as 'like bamboo'; second, as the large atypical canes from Fu-Nan. *S. officinarum* and *S. sinense* were probably present but they were not distinguished conceptually as groups. We contrast this conclusion with the findings of the renowned historian of Chinese agriculture Shih Shêng-Han[1] who has written a commentary on Chia Ssu-Hsieh's *Chhi Min Yao Shu* of c. +535. He distinguished four groups amongst these early characters for sugarcane by pronunciation. One is tempted to try and relate these to species, however, I conclude that the groups arose from transliteration of sounds from Yüeh languages and the problems of rhyming, rather than indicating genetic differences. In the +17th century, Rumphius wrote in his *Herbarium Amboinense* that the Chinese used *tecsia* (bamboo cane, *S. sinense*) to make sugar, while 'all other thicker canes are called *camsia*'. This appears to indicate a clear recognition linguistically of the two species *S. sinense* and *S. officinarum* in China, but the time scale of this comparison remains unknown, and there is no obvious relationship with Shih Shêng-Han's commentary.

The additional compound mentioned by Hsi Han, *kan*[1] *chê*[2], needs some discussion. It has been employed to this day by encyclopaedists as an inclusive term for all species of sugarcane. George Watt in his comprehensive *Dictionary of the Economic Products of India* derived the Chinese *kan* from the Sanskrit *khanda*:[a]

> It is significant that the word *kan*[2] (sweet) in Chinese should bear so close a resemblance to the Sanskrit *Khanda* which has very nearly the same meaning and even denotes the plant in some Aryan languages of India. *Kanche* in Chinese (the name for the cane) literally means sweet bamboo.[b]

The Urdu name for sugarcane was *ganna*[c] and the sweet cane of the Old Testament was *kaneh*.[d] All these appellations were pronounced similarly and could have formed an international *patois* for sugarcane along the Silk Road. Since the combination *kan*[1] *chê*[2] appeared in an early Chinese Buddhist sutra, the *Chuan Chi Pai Yüan Ching*[3] (*Avadānasataka*) translated somewhere between +223 and +253,[e] I suggest that this *patois* may have been introduced under Buddhist influence. *Kan*[1]*chê*[2] is such a perfect choice for translating sugarcane,[f] that it has the appearance of formal selection, perhaps by a group translating Buddhist sutras, taking into account the sounds involved.

[a] Watt (1), vol. 6, pt 2, p. 50.
[b] As we remarked earlier *kan chê* literally means sweet sugarcane, not sweet bamboo.
[c] Watt (1), vol. 6, pt 2, p. 66.
[d] Moldenke & Moldenke (1), p. 214.
[e] Taishō no. 200 (Nanjio no. 1324), pp. 222–3.
[f] *Kan*[1] means sweet, *chê*[2] sugarcane.

[1] 石聲漢 [2] 甘 [3] 撰集百緣經

(4) Identification of Sugarcane Species in China after +670

The appearance of a set of terms for describing different clones or varieties of particular plants, reflected a widening of the genetic base, one of the essential basic steps in improving agricultural yields. It indicated that humans had recognised the clonal diversity in the physiological features of the plant, and had equated them with different usages. In the beginning, such differentiation was based on immediate utility, variations in the colour of the plant, the size of the stalk and leaves, and only later came to include the peculiarity of yields and adaption to climate. After the +7th century, the pharmacopoeias provided names that enabled distinction between the two species, *S. officinarum* and *S. sinense*.[a] I have assembled in Table 12 a selection of references to clone names useful in identifying the two species in China. Most of the descriptions proved inadequate individually for identifying the species, however when reviewed as a whole a reasonable consensus emerges.

Thao Hung-Ching[1] in the *Pên Tshao Ching Chi Chu*[2] of +492 gave the first comparative information between north and south of the ranges. He contrasted miscanthus cane (*ti chê*[3]), with a clone in Kuang-Tung, which grew as large as bamboo:[b]

> A type in Kuang-Chou grows big like bamboo (*ta ju chu*[4]) after several years [reaching] over one chang [approx. 2.45m] in height. The juice can be used to make *sha thang*[5], which is extremely beneficial to people [i.e. it can be used as a medicine]. There is also miscanthus cane (*ti chê*[2,3]) with few nodes (*chieh*[6]) and thin [stalks] which can be chewed.

Daniels & Daniels[c] have claimed that this indicates the first differentiation between ('type big like bamboo') and *S. barberi* ('miscanthus cane, thin stalks').[d] In addition, they interpreted the following passage in Mêng Shên's *Shi Liao Pên Tshao* of +670: 'There is a red coloured sugarcane called *khun-lun chê*[2,7], and a white coloured cane called miscanthus cane *ti chê*[2]. The best bamboo cane *chu*

[a] Apart from the two main clones and variants mentioned below, which can be readily assigned to one of the two species, texts did mention others. For the most part these were impossible to assign to species owing to the paucity of botanical description, and because they often only appeared in the literature once. For example the *Chhing I Lu* of +950 (p. 20b) listed *chia chê*[2,8] (propping up cane), *miao chê*[2,9] (seeding cane), *chhing-hui chê*[2,10] (green ash cane), *kuang-lang chê*[2,11] (sugar palm cane), *pai-yen chê*[2,12] (white rock cane), *chia-feng chê*[2,13] (pseudo-honey bee cane) all of which were recorded as growing in the Wu[14] region. This problem was not confined to China, cultivators everywhere renamed clones after people, place names, descriptive epithets and as the spirit moved them, see Brandes (1), pp. 5–6.

[b] The *Pên Tshao Ching Chi Chu* is now lost, but the sugar section is preserved in the *PTKM*, see pp. 1888–9.

[c] Daniels & Daniels (2), p. 44.

[d] Daniels & Daniels (2), p. 36 referred to Jeswiet (1) in which *S. sinense* and *S. barberi* are separated on the basis of leaf width, which is proportional to stalk diameter.

[1] 陶弘景 [2] 本草經集注 [3] 荻蔗 [4] 大如竹 [5] 沙糖
[6] 節 [7] 崑崙蔗 [8] 夾蔗 [9] 苗蔗 [10] 青灰蔗
[11] 枨榔蔗 [12] 白岩蔗 [13] 假蜂蔗 [14] 吳

chê[2,1] is grown in Shu [Ssu-Chhuan] and Ling-Nan',[a] to indicate the presence of *S. officinarum*, *S. barberi* and *S. sinense* in China during the Thang. This hypothesis identified *S. barberi* as *ti chê*[2] by thin stalks, and subsequently *ti chê*[2] was usually described as having thin stalks. Ancient scholars were saying in effect: north of the ranges there was a thin sugarcane looking like miscanthus, while south of the ranges there was a thick sugarcane looking like bamboo. As there are no non-*S. officinarum* clones from China in the World Collection of sugarcanes held in Florida, USA, that are not *S. sinense*, and as Chinese plant collectors have not found any *S. barberi* clones in modern China,[b] it appears that *ti chê*[2] served as a synonym for *chu chê*[2], *S. sinense*, north of the ranges. The different phenotypes of *S. sinense* north and south of the ranges arose due to temperature, rainfall and soil type. The southern, warmer, moist climate and better soils on fertile flood plains fostered larger thicker stalks 'big like bamboo', while the cooler, drier climate north of the Nan-Ling ranges combined with poorer soils yielded thin stalks looking like miscanthus *ti chê*[2]. This is supported by the fact that the name *ti chê*[2] did not appear south of the ranges until sugarcane cultivation expanded onto poorer hill land after the +16th century. We can conclude, as a generalisation, that *S. sinense* was called bamboo cane, *chu chê*[2], south of the Nan-Ling ranges, and miscanthus cane, *ti chê*[2] north of them. This variation of clone phenotype with climate was so well known that it does not need documenting.[c] As the Chinese did not recognise this paradox, it indicates that they did not have a clear concept of genotype and environment interaction, as I shall discuss below (pp. 162–7).

Yet, I have found some texts such as Su Sung's[2] *Pên Tshao Thu Ching*[3] of +1061, which described both *ti chê*[2] and *chu chê*[2,d].

> There are two kinds. Miscanthus cane (*ti chê*[2]) has leaves like miscanthus (*ti*),[4] slender and short stalks, and widely separated nodes; and though only suitable for eating raw, they may also be boiled to make a sugary syrup (*hsi thang*[5]). Bamboo cane (*chu chê*[2]) has thick tall stalks, and can be pressed to make *sha-thang*. Much is made in Chhüan-Chou[6], Fu-Chou[7], Chi-Chou[8] and Kuang-Chou[9]. Only Shu Chhuan[10] (Ssu-Chhuan) makes milk clarified sugar (*ju thang*[11]) by boiling *sha thang* and adding cow's milk. Southern people take much miscanthus cane (*ti chê*[2]) and little bamboo cane (*chu chê*[2]) to sell in the northern regions.

Another one was a passage in an +18th-century gazetteer for Yen-Thing county[12], Thung-Chhuan[13] prefecture in Ssu-Chhuan province, which cited three

[a] Cited in *PTKM*, p. 1889.

[b] Interviews with Professor Ho Shun-Chhang[14] of Yunnan Agricultural University at Khun-Ming[15] on the 4th August 1989.

[c] See Edwards (1), vol. 2, pp. 209–10 for a graphic description of sugarcane variation caused by environment.

[d] Quoted in the *PTKM*, p. 1889.

[1] 竹蔗 [2] 蘇頌 [3] 本草圖經 [4] 荻 [5] 稀糖
[6] 泉州 [7] 福州 [8] 吉州 [9] 廣州 [10] 蜀川
[11] 乳糖 [12] 鹽亭縣 [13] 潼川府 [14] 何順長 [15] 昆明

Table 12. *A selected listing of sources that recorded sugarcane species in China*[a]

Date	Source	*S. officinarum*	*S. sinense*
+492	*Pên Tshao Ching Chi Chu*[b]		*chu chê*[1], *ti chê*[2]
+670	*Shih Liao Pên Tshao*[c]	*khun-lun chê*[3]	*chu chê*[1], *ti chê*[2]
+1061	*Pên Tshao Thu Ching*[d]		*chu chê*[1], *ti chê*[2]
+1154	*Thang Shuang Phu*[e]	*khun-lun chê*[3] *hung chê*[6]	*tu chê*[4], *lê chê*[5] *hsi chê*[7]
+1100/+1250	*Shih Lin Kuang Chi*[f]	*khun-lun chê*[3] *Chiao-Chih chê*[8] *Fu-Fêng chê*[9] *hung chê*[6]	*tu chê*[4], *lê chê*[5]
+1223	*Chhih-Chheng Chih*[g]		*chu chê*[1], *ti chê*[2]
+1265/+1274	*Lin An Chih*[h]	*kan chê*[10]	*ti chê*[2], *lu chê*[11]
+1344	*Chin Ling Hsin Chih*[i]		*chu chê*[2], *ti chê*[2]
+1561	*Kuang-Tung Thung Chih*[j]	*khun-lun chê*[3]	*chu chê*[1], *ti chê*[2]
c. +1580	*Min Pu Su*[k]	*shih chê*[12]	*i chê*[13]
+1595	*Thien Chung Chi*[l]	*khun-lun chê*[3]	*chu chê*[1], *la chê*[14], *ti chê*[2]
+1596	*Pên Tshao Kang Mu*[m]	*khun-lun chê*[3] *hung chê*[6] *tzu chê*[15]	*tu chê*[4], *ti chê*[2] *chu chê*[2]
+1612	*Chhüan Chou Fu Chih*[n]	*kan chê*[10]	*ti chê*[2]
+1613	*Fu Chou Fu Chih*[o]	*khun-lun chê*[3] *chang chê*[16]	*ti chê*[2]
+1636	*Yu Hsi Hsien Chih*[p]	*hung kan chê*[17] *chhing-thung chê*[18]	*chu chê*[1]
+1637	*Thien Kung Khai Wu*[q]	*khun-lun chê*[3]	*ti chê*[2], *thang chê*[19]
c. +1650	*Fu Chhing Hsien Chih Hsü Lüeh*[r]	*khun-lun chê*[3]	*tu chê*[4], *lê chê*[5]
+1684	*Ning Hua Hsien Chih*[s]	*khun-lun chê*[3]	*chu chê*[1], *ti chê*[2]
+1687	*Yang Chhun Hsien Chih*[t]		*chu chê*[1], *la chê*[20]
+1700	*Chang Phu Hsien Chih*[u]		*chu chê*[21], *tu chê*[4], *Chien chê*[22]
+1700	*Kuang-Tung Hsin Yü*[v]	*khun-lun chê*[3] *yao chê*[23] *pai chê*[24] *hsüeh chê*[25] *Fu-Nan chê*[26]	*chu chê*[1], *ti chê*[2]
+1717	*Lo Fou Shan Chih Hui Pien*[w]	*khun-lun chê*[3]	*la chê*[20], *ti chê*[2]
+1732	*Yung An Hsien Chih*[x]		*ti chê*[2], *thang chê*[19]
+1752	*Ting Chou Fu Chih*[y]	*khun-lun chê*[3] *shih chê*[12]	*ti chê*[2] *i chê*[13]
+1763	*Chhüan Chou Fu Chih*[z]	*kan chê*[10] *khun-lun chê*[3]	*chien chê*[22] *ti chê*[2]
+1786	*Yen Thing Hsien Chih*[aa]	*khun-lun chê*[3]	*chu chê*[1], *ti chê*[14], *ti chê*[2]
+1787	*Yung Chhun Chou Chih*[ab]	*kan chê*[10] *khun-lun chê*[3]	*chien chê*[22], *ti chê*[2] *pheng chê*[27]
+1787	*Chung Chiang Hsien Chih*[ac]	*khun-lun chê*[3]	*chu chê*[1], *la chê*[14], *ti chê*[2]
+1790	*Flora Cochinchinensis*[ad]	*rubrum* *elephantinum*	*album* *Mia lau*
+1798	*Thung An Hsien Chih*[ae]	*kan chê*[10]	*ti chê*[2]

Table 12. (*cont.*)

Date	Source	*S. officinarum*	*S. sinense*
1820	*Phing Yuan Hsien Chih*[af]	*khun-lun chê*[28]	*chu chê*[29], *la chê*[30], *ti chê*[31]
1821	*Yang Chhun Hsien Chih*[ag]	*kan chê*[10]	*chu chê*[1]
1832	*Shun Chhang Hsien Chih*[ah]	*kan chê*[10]	*chu chê*[1]
1864	*Shang Hang Hsien Chih*[ai]	*khun-lun chê*[3]	*ti chê*[2], *i chê*[13]
1892	*Wu Chhüan Hsien Chih*[aj]	*khun-lun chê*[3] *la chê*[20]	*ti chê*[2], *mao chê*[32], *chu chê*[1]
1903	*Fu Chün Nung Chhan Khao Lüeh*[ak]	*tu tzu chê*[33]	*kan chê*[10], *mao chê*[32]
1934	*Ning Shu Thang Yeh Kai Khuang*[al]	*hung chê*[6] *pai chê*[24]	*lo-han chê*[34], *hsi chê*[35]
1936	*Shisen Shō Sōran*[am]	*hung chê*[6]	*hsiao li yeh*[36]

[a] This table does not aim to be exhaustive, but merely to provide the reader with a general idea of the situation. My identifications of Chinese terms for species are based on descriptions given in the sources.

[b] Quoted in *PTKM*, pp. 1888–9. Note that the term *chu-chê*[1] did not appear in this text, but from the description, 'large resembling bamboo and over a *chang*[37] [2.45 m] tall'; it was undoubtedly *chu-chê*[1].

[c] Quoted in *PTKM*, p. 1889.

[d] Quoted in *PTKM*, p. 1889.

[e] p. 3a.

[f] ch. 10, p. 9a.

[g] ch. 36, p. 13a (p. 7348).

[h] ch. 56, p. 11a (p. 4413). Note that the term *lu chê* did not actually appear in the text, but the description 'ones small like lu[38] [*Phragmities communis* Trin. R754] are called miscanthus cane (*ti chê*[2])' allows my interpretation. The same passage appeared in the *Mêng Liang Lu* (ch. 18, p. 6a) of +1275.

[i] ch. 7, p. 33b (p. 1868).

[j] ch. 23, p. 14a.

[k] p. 13.

[l] ch. 53, p. 17a.

[m] p. 1889.

[n] ch. 3, p. 43a.

[o] ch. 37, p. 6a.

[p] ch. 4, p. 8b and ch. 4, p. 10b.

[q] pp. 162–3.

[r] ch. 2, *shang*, p. 13b.

[s] ch. 2, p. 67b.

[t] ch. 14, p. 10b.

[u] ch. 4, p. 11b.

[v] p. 689.

[w] ch. 7, p. 25a.

[x] ch. 5, p. 3a.

[y] ch. 8, pp. 2b–3a; ch. 8, p. 6b.

[z] ch. 19, p. 10a.

[aa] ch. 4, p. 16b.

[ab] ch. 7, p. 13b and ch. 7, p. 24b.

[ac] ch. 3, pp. 5a–b.

[ad] vol. 1, p. 52.

[ae] ch. 14, pp. 20a–b

[af] ch. 2, p. 43b.

[ag] ch. 1, p. 46a.

[ah] ch. 3, p. 22b.

[ai] ch. 11, p. 8b; ch. 11, p. 16a.

[aj] ch. 2, p. 30a. The term *khun-lun chê*[3] did not appear in this text, but from the description, 'The rind is either red or purple. People eat a lot of it.' I concluded that it belongs to this clone. It should also be noted that *mao chê*[32] appeared in early 19th-century gazetteers for Kuang-Tung province such as the 1811 *Lei-Chou FC*, ch. 2, pp. 51b–52a and the 1843 *Ying-Tê HC*, ch. 16, p. 18b, and later in the 1871 *Phan-Yü HC*, ch. 7, p. 3a and the 1874 *Shao-Chou FC*, ch. 11, p. 29a.

[ak] Ho Kang-Tê (*1*), ch. 2, p. 10a.

[al] Anon (*552*), p. 66–7.

[am] Kanda (*1*), pp. 519–20.

[1] 竹蔗 [2] 荻蔗 [3] 崑崙蔗 [4] 杜蔗 [5] 芳蔗
[6] 紅蔗 [7] 西蔗 [8] 交趾蔗 [9] 扶風蔗 [10] 甘蔗
[11] 藘蔗 [12] 食蔗 [13] 飴蔗 [14] 蠟蔗 [15] 紫蔗
[16] 杜蔗 [17] 紅甘蔗 [18] 青簡蔗 [19] 糖蔗 [20] 臘蔗
[21] 諸蔗 [22] 管蔗 [23] 藥蔗 [24] 白蔗 [25] 雪蔗
[26] 扶南蔗 [27] 蓬蔗 [28] 崑崙蔗 [29] 竹蔗 [30] 蠟蔗
[31] 荻蔗 [32] 茅蔗 [33] 肚子蔗 [34] 羅漢蔗 [35] 細蔗
[36] 小立葉 [37] 丈 [38] 藘

types of sugarcane: red *khun-lun chê*, white bamboo cane (*chu chê*[2]), also known as wax cane (*la chê*[2,1]), and miscanthus cane (*ti chê*[2]), described as small with a low juice content but used for sugar making.[a]

On face value, these texts recorded two non-*S. officinarum* clones, and the differences observed probably arose from growing canes on nearby contrasting areas such as irrigated, deep soil versus unirrigated thin hillside soils. However, at this stage we must keep an open mind on the identity of clones north of the Nan-Ling ranges in certain special areas. The *Thang Shuang Phu* of c.+1154 recorded *hsi chê*[2,2], western cane in Ssu-Chhuan, and it could have been *S. barberi* transported from India and Persia.[b]

We will now review what is known of *S. sinense* on the world stage and *S. officinarum* in China.

(5) *S. sinense* Roxb (Bamboo Cane, *chu chê* and Miscanthus Cane, *ti chê*)

I discussed previously the possibility that the Chinese sugarcane, *S. sinense* arose either through hybridisation between *S. officinarum* from New Guinea and the wild cane, *S. spontaneum* of China, or alternatively, from indigenous taxa unidentified as yet. This remains a matter of intensive investigation at the moment. Whatever the phylogeny of *S. sinense*, the best guess is that it probably evolved in Yunnan and adjacent areas, including north Vietnam.[c] This corresponded to the area of distribution of the basic *Saccharum* species, *S. spontaneum*, and there are closely related wild species such as *Erianthus arundinaceus* (Retz.) Jesw.,[d] *Miscanthus sacchariflorus* Maxim. Benth. and *Miscanthus sinensis* Anderss.

The significance of the Chinese discovery of *S. sinense* for agricultural cultivation was first, that it provided higher sucrose yielding clones for southern China and, second, that the greater cold tolerance of these clones allowed the expansion of sugar production north of the ranges up to at least 30°N in central China. *S. sinense* provided the major clones for the commercial production of sugar in south and central China, and nearby areas in South-East Asia, Tai-

[a] +1786 *Yen-Thing HC*, ch. 4, p. 16b. Low juice means high fibre (additional fuel for boiling), and it does not mean that the juice was not very sweet.

[b] In addition, if *S. sinense* has a deep time scale of 6,000 years, some further hybridisation between *S. sinense* and some grass such as *S. spontaneum* L., *Miscanthus sinensis* Anderss. or *M. sacchariflorus* Maxim. Benth, could be expected. *S. officinarum* is excluded in central China, as it is very sensitive to photoperiod and temperature and will not flower at latitudes greater than 22°–25°N (Bull & Glasziou [1], p. 6). Flowering is so poor in south China that modern sugarcane breeding programmes are conducted on Hainan island (Chen Ching-Long [1], p. 417). Local development of other clones by hydridisation north of the ranges was possible but not a strong hypothesis.

[c] In these areas French scientists (Crevost and Lemarié (1), pp. 340–7) recorded *S. sinense* as *miá lan* and *miá re* in Tonkin, and *miá lau* in Cochin China.

[d] Chinese taxonomists identified this taxon as *Saccharum arundinaceum* Retz., see Chhing Kung Yeh Pu . . . (1), p. 58.

[1] 蠟蔗 [2] 西蔗

wan, Okinawa and Japan until the implementation of modern breeding and introduction programmes in the 20th century.

The Chinese likened sugarcane to bamboo quite early. I commented on the advent of characters such as *kan*[3] meaning bamboo pole in Table 11[a]. Hsi Han, in his *Nan Fang Tshao Mu Chuang* of +304, talked of *kan*[1] *chê*[2] as greatly resembling bamboo.[b] Thao Hung-Ching in +492 mentioned a sugarcane resembling 'big bamboo', which was grown in Kuang-Tung for making *sha-thang*. Though these sources were not species specific, we do know from Mêng Shên's *Shih Liao Pên Tshao* of c. +670 that *S. sinense* was known as *chu chê*[2], bamboo cane south of the ranges. Bamboo cane is used in some modern Chinese scientific publications as the representative name for *S. sinense*.[c]

Although *S. sinense* was commonly called *chu chê*[2] or bamboo cane in south China, it appeared as Tekcha, Uba, Zwinga (Zwenga), etc., in modern collections.[d] The word Tekcha was the Southern Min dialect reading of the characters *chu chê*[2], and was the same in the Teochew dialect.[e] As noted earlier, Rumpf in the +17th century was the first European to record the Chinese name for bamboo cane as Tecsia, and it became transcribed as Tekcha in later scientific literature. He remarked that the Chinese distinguished *tecsia* (*S. sinense*) as different from the other thicker sugarcanes of south China (*S. officinarum*) which they called *camsia*.[f]

Specific descriptions of *S. sinense* occurred rarely in Chinese literature. The first substantive description of bamboo cane appeared in the *Flora Cochinchinensis* of Father Joannis de Loureiro published in +1790. A variety *album* identified as *S. sinense* by its Tonkinese name Miá lau was described:[g]

Album called Miá lau, stalks: long, white, medium thickness, very sweet, long internodes

which contrasts with *khun-lun chê*, *S. officinarum* var. *rubrum* of which he wrote:

Rubrum called Miá mung, stalks: short, thick, red, very juicy, internodes compressed

The key differences between these two clones lay in thickness (*S. officinarum*) and length of internode (*S. sinense*). To date we have spoken of *S. sinense* as if it were a single clone, however studies of modern clone collections have indicated a num-

[a] The 1884 gazetteer for Fu-An[1] county in Fukien equated the compound *kan*[3]*chê*[2,2] which appeared in the *NFTMC* with bamboo cane explaining that the stalk of the sugarcane resembled that of the bamboo, see the 1884 *Fu-An HC*, ch. 7, p. 5b. The *Chhih Khan Pi Than*, which depicted sugar production on Taiwan during the late +17th and early +18th centuries, also equated the compound *kan chê*[2,3], in which *kan*[4] referred to an unidentified grass, with bamboo cane, cited in *THSCL*, p. 52.

[b] *NFTMC, shang*, p. 4b. See Vol. 6, pt 1, pp. 447ff for a discussion of the authenticity of the *NFTMC*.

[c] Okade (1), pp. 6–8; Phêng Shih-Chiang (3), p. 247.

[d] Artschwager (2), Pansahi group, p. 5.

[e] Douglas ((1), p. 485) has '*tek-chia*, the common sugar-cane, not the sort sold for chewing' and MacGowan ((1), p. 515) remarked that *tek tsia* was for making sugar while *kam tsia*, the Southern Min reading of the characters *kan*[1] *chê*[2], was for eating. In Teochew it was Tek-chia, see Goddard (1), pp. 16 and 163.

[f] Rumphius (1), vol. 5, p. 188.

[g] de Loureiro (1), vol. 1, p. 52.

[1] 福安縣 [2] 竿蔗 [3] 竹蔗 [4] 竹

ber of clones which can only be distinguished with great difficulty. Nevertheless, there was some genetic variation as chromosome number ranged from 2n = 115 to 120,[a] and there was some difference in leaf flavonoids between clones.[b] This variation arose sexually as some *S. sinense* clones produced a small amount of pollen, and Earle in Puerto Rico bred one clone CH64921 which he claimed to be a self of *S. sinense* clone, Uba.[c] Mutations of existing clones evidently occurred; Kavangire is assumed to be a mutant form of Uba, from which it is only distinguished with great difficulty.[d] Grassl[e] suggested the presence of two groups under *S. sinense*, and this has been retained pending further research by Daniels and Roach.[f] Daniels *et al.*[g] have shown that this concept was erroneous and provided a circumscription for *S. sinense* and keys for distinguishing it from *S. barberi.*

North of the Nan-Ling ranges *S. sinense* looked different with thinner, trashier stalks in particular. Bamboo cane was no longer an appropriate epithet and the Chinese employed the term *ti chê*[2,1] for *S. sinense*, after *ti*[2], *Miscanthus sacchariflorus* Maxim. Benth, which has a distribution of central and northern China.[h] Outside of the distribution of *Miscanthus sacchariflorus* on Hainan Island and in Taiwan, the Chinese coined an alternative name *mang chê*[2,3], with *mang*[4] referring to *Miscanthus sinensis* Anderss., a large robust reed, often appearing as an ornamental in Western botanical gardens.[i] *Lu chê*[2,5] (*lu*[6] meant *Phragmites communis* Trin.) was also used as a name mainly in Ssu-Chhuan and Yunnan provinces.[j] Both *ti* and *lu* were very appropriate descriptions of these plants as they have thinner, robust stalks, and a row of root eyes and a bud at each node, like *Saccharum.* From the botanical point of view *ti* and *lu* were more accurate names than *chu*[7] (bamboo) and *mang* which lack root eyes and a bud at the nodes. *Ti*, *mang* and *lu* were all descriptive of *S. sinense* crops affected by cooler weather, marginal rainfall or poorer soils.

Chinese sources occasionally referred to *S. sinense* by the name *la chê*[2,8] wax

[a] Most common number 2n = 116 (Paton, Daniels, Smith & Williams (1), p. 44).
[b] Paton, Daniels, Smith & Williams (1).
[c] Earle (1), pp. 66–7.
[d] Rosenfeld (1), p. 155.
[e] Grassl (10), pp. 18–20.
[f] Daniels & Roach (1), p. 36.
[g] Daniels, Roach, Daniels and Paton (1).
[h] For example, Su Sung in his *Pên Tshao Thu Ching* (quoted in *PTKM*, p. 1889). See Adati & Shiotani (1), p. 18, for the distribution of *M. sacchariflorus* and *M. sinensis.*
[i] On Hainan island *mang chê*[2] was recorded in the 1820 *Chhêng-Mai HC*, ch. 10, p. 7a. For Taiwan, see the *THSCL*, pp. 51–3.
[j] Chhing Kung Yeh Pu ... (1), p. 111. The *Mêng Liang Lu* of +1275, p. 284 recorded that near Lin-An (present day Hangchow in Chekiang), the capital of the Southern Sung, there was a sugarcane 'small resembling *lu* [*Phragmites communis* Trin.] called miscanthus cane (*ti chê*[2]) and was also sweet' (the same passage was also quoted in the *Lin An Chih* of +1265 to +1274, p. 4413).

[1] 荻蔗 [2] 荻 [3] 芒蔗 [4] 芒 [5] 蘆蔗
[6] 蘆 [7] 竹 [8] 蠟蔗

cane, because of a heavy wax coating under some circumstances.[a] In this respect it is interesting to note the documentation of a clone known as bamboo cane wax (*chu chê*[2] *la*[1]) which was described as intermediate between *la chê*[2] and *chu chê*[2,2] in Hai-Yang county[3], Chhao-Chou prefecture[4], Kuang-Tung province.[b] This indicated a possible recognition of minute differences between clones or more probably a confusion of a single clone growing in different micro-environments. In Tung-Kuan county[5] near Kuang-Chou city, *S. sinense* was also referred to as *shan chê*[2,6] or mountain sugarcane during the +17th century, indicating expansion onto hilly land at that time.[c] The *Thang Shuang Phu* of c.+1154, one of the first substantial monographs on sugar and sugarcane in the world, referred to *S. sinense* by the name *tu chê*[2,7], pale purple cane.[d] Under some climates *S. sinense* has a pale purple stalk, and Noel Deerr provided a coloured plate of a pale purple *S. sinense* clone, Uba.[e] *Lê chê*[2,8] was another synonym for *S. sinense* in the *Thang Shuang Phu*,[f] and these varying epithets indicated effects of micro-environment or different clones within the species. Other sources mentioned minor terms *mao chê*[2,9] or couch grass cane,[g] and *thang chê*[2,10],[h] or literally sugarcane named because it was specially cultivated for boiling into sugar.

Confusion in the literature has arisen from two sources. First, F. Porter Smith

[a] Okade (*1*), p. 8 identified wax cane, *la chê*[2] or *la cha*, the Southern Min dialect reading of the same characters, as a mutation of bamboo cane (*chu*[3] *chê*[2]).

[b] 1900 *Hai-Yang HC*, ch. 8, p. 3a.

[c] +1689 *Tung-Kuan HC*, ch. 2/4, p. 2a.

[d] *TSP*, p. 3a.

[e] Deerr (2), pl. 10 (cv. Uba).

[f] *TSP*, p. 3a was the first source to mention *lê chê*[2]. The *PTKM*, p. 1889 commenting on the clones given in the *TSP* remarked, '*Lê chê*[2], also called *la chê*[2] (wax cane), is miscanthus cane. It can be used to make *sha-thang*.' The *Fu Chhing Hsien Chih Hsü Lüeh* of the early Chhing (Fukien province), ch. 2, shang, p. 13b recorded: '*Lê chê*[2] has a thick rind and a small hard stalk and the juice can be pressed to boil black sugar (*hei thang*).' Note that there may have been clones of *S. officinarum* with a wax coating as the 1892 *Wu-Chhuan HC* (Kuang-Tung province), ch. 2, p. 30a stated: 'One type [of sugarcane] is large, [the stalk] being one *tshun* [3 cm] in diameter and five or six *chih* [1.5–1.9 m] in length, and the internodes over two *tshun* [6 cm long]. The rind is either red or purple and people eat it a lot. It is known locally as *la chê*[2].'

[g] Ho Kang-Tê (Ho (*1*) ch. 2, p. 10a) recorded *mao chê*[9] as one of the three clones used for sugar making in Fu-Chou[11] prefecture, Chiang-Hsi province, in the late 19th early 20th centuries and described it as 'a small stalk with sparse internodes, and scattered leaves resembling *lu* [*Phragmities communis* Trin R754]' and added that it was 'exclusively used for making white sugar'. The following gazetteers indicated that *mao chê*[2] was cultivated in Kuang-Tung during the 19th century for making into sugar: 1811 *Lei-Chou FC*, ch. 1, pp. 51b–52a; 1843 *Ying-Te HC* (Shao-Chou prefecture), ch. 16, p. 18b; 1871 *Phan-Yü HC* (Kuang-Chou prefecture), ch. 7, p. 3a; and the 1874 *Shao-Chou FC*, ch. 11, p. 29a. The 1892 *Wu-Chhuan HC* (Chhiung Chou prefecture), ch. 2, p. 30a stated that *mao chê*[2] and *chu chê*[2] were the variant local names of *ti chê*[2], the clone used for sugar making.

[h] *TKKW*, p. 162; the +1732 *Yung-An HC* (Yen-Phing prefecture, Fukien) ch. 5, p. 3a stated that *ti chê*[2] was locally known as *thang chê*[10], in the 1832 *Chêng Ho HC* (Chien-Ning prefecture, Fukien), ch. 1, p. 37a it is said that, 'the one with small stalks (*ken*) is locally known as *thang chê*[10]; the first known appearance of the term *thang chê*[10] was in a gazetteer for a prefecture in Chekiang province, the +1605 *Wên-Chou FC*, ch. 5, p. 44a, which listed it without any explanation.

[1] 竹蔗蠟 [2] 竹蔗 [3] 海陽縣 [4] 潮州府 [5] 東莞縣
[6] 山蔗 [7] 杜蔗 [8] 芳蔗 [9] 茅蔗 [10] 糖蔗
[11] 撫州府

in his *Contributions Towards the Materia Medica and Natural History of China* identified *ti chê*[2] as sweet sorghum, *Sorghum saccharatum*.[a] In his 1911 revision of F. Porter Smith, G. A. Stuart listed *ti chê*[2], *la chê*[2], and *lê chê*[2] as synonyms for sweet sorghum.[b] Second, Michael Hagerty in a major paper on Chinese sorghums also equated *ti chê*[2] with *Sorghum saccharatum* Pers. He cited the 1915 work of Matsumura and the above-mentioned study by Stuart as authorities.[c] These identifications need not be considered seriously as the descriptions in the original Chinese sources cited above taken in context confirm that what was being referred to was sugarcane not sorghum.[d] This conceptual error caused Hagerty to write in surprise and confusion:[e]

> Following the precedent set by all the early authors of Chinese herbals, the *kan*[1] *chê*[2] or *Saccharum officinarum* and *ti chê*[2] or *Sorghum saccharatum* are treated together in the *Pên Tshao Kang Mu*, 33: 13, but neither of these two are mentioned in the account of *Sorghum vulgare* which is given in 23: 27 of the above work.

I conclude that Chinese herbalists knew more about *Saccharum* in China than their European and Japanese counterparts. Stuart, Hagerty and Matsumura need not be considered further.

Apart from the immediate Chinese environment, *S. sinense* has had considerable impact in sugarcane areas around the world. It served as a major cultivar in South-East Asia until the 20th century, known as *mia lan* and *miá re* in Tonking, *miá lau* in Cochin China and *ampou hen* in Cambodia.[f] *S. sinense* achieved prominence in Taiwan by at least the +17th century, and remained dominant for 300 years, until the Japanese introduced exotic clones in the 20th century. In Taiwan, the Chinese called it bamboo cane, *chu*[3] *chê*[2] or Tekcha, the Southern Min dialect reading of the same characters.[g] The term *mang chê*[2], with *mang* referring to *Miscanthus sinensis* Anderss., was also used, and probably described poor crops.[h] In modern clone collections in Taiwan,[i] wax cane (*la chê*), red cane (*hung chê*[2,1]), green rind cane (*chhing-phi chê*[2,2]), young bamboo cane (*chu-tsai chê*[2,3]) and southern tribute cane (*nan-kung chê*[2,4]) have all been identified as variants of bamboo cane. Bamboo cane was transferred shortly after the +17th century to the Ryūkyū islands and thence to the Japanese home islands, where it was known as *chikusha*[5] or *chikusho*[5] (two variant Japanese readings of the same characters). *Chikusha* continues to be employed in cultivation today for the pro-

[a] Smith, F. Porter (1), p. 202. *Sorghum saccharatum* is now classified as *Sorghum bicolor* Moench. var. *saccharatum*.
[b] Stuart (1), p. 386.
[c] Hagerty (17), p. 238; Matsumura (1), p. 25; Stuart (1), pp. 386 and 416.
[d] For example, see the definitive *TKKW* of +1637, pp. 162–3.
[e] Hagerty (17), p. 237.
[f] Crevost and Lemarié (1), pp. 340–7.
[g] +1691 *Thai-Wan FC*, p. 79 mentioned bamboo cane. Okade (1), p. 8.
[h] See the *THSCL*, pp. 51–3.
[i] Okade (1), p. 8. Red cane (*hung chê*[2]) appeared to be an anomaly as the circumscription of *S. sinense* did not include red sugarcanes.

[1] 紅蔗 [2] 青皮蔗 [3] 竹仔蔗 [4] 南貢蔗 [5] 竹蔗

duction of speciality *wasanbon*[1] sugar in Kagawa[2] and Tokushima[3] prefectures, but has largely been replaced by hybrid clones imported or selected in Japan from canes raised from imported seed.[a] Zwinga, or Japanese cane as it was called in the scientific literature, a clone of *S. sinense*, was transferred to Louisiana from Japan in 1877 by General Le Duc, Commissioner of Agriculture.[b] Zwinga was very akin to, but distinct from Tekcha, and was extensively used in the United States as a fodder cane.[c] Subsequently a total of fourteen *S. sinense* clones were introduced into the United States of America and were tested extensively as sugar producers.[d]

William Roxburgh introduced *S. sinense* from Canton into the Calcutta botanical gardens in +1796.[e] He gave it a Linnean binomial and botanical description; this is discussed in more detail below. From Calcutta, it spread over India and achieved a niche as a chewing cane and a minor commercial variety in the unfavourable climate of north India.[f] It also achieved some prominence in the European plantation system during the 19th century. Leonard Wray explained its attributes as 'extreme hardiness in withstanding heat and cold, white ants, jackals etc.'[g] *S. sinense* first appeared elsewhere in Western literature as a cultivar 'Uba' introduced from Brazil to Natal in 1882.[h] Uba, an American Indian name for reeds and a secondary name for sugarcane,[i] had been in Brazil for an indeterminate time, and was most probably introduced from India or China by the Portuguese. It achieved immediate success in Natal because of high yields, adaption to cold and virtual immunity to the viral disease, mosaic.[j] Uba rapidly became the standard clone because of an outbreak of mosaic, and it remained the predominant clone in Natal of fifty years.[k] The same sugarcane was introduced into Madeira during the late 19th century to solve serious disease and pest problems. here it also proved a great success and benefited both the grape and sugar industry as half of the sugar manufactured in Madeira at this time was turned into alcohol for producing the celebrated Madeiran fortified wines.[l] *S. sinense* was transferred from Brazil to Argentina where it became

[a] Matsui & Kitagawa (1), p. 655.

[b] Dymond (1), pp. 460–1. Also see Earle (1), p. 324. Rosenfeld ((1), p. 163) was incorrect in saying that the date of introduction to Louisiana was unknown. Stubbs (1), p. 851 gives a brief account of the possible contribution Zwinga cane would make to future breeding as perceived in the early 1890s.

[c] Earle (1), p. 324.

[d] *Ibid.*, p. 270.

[e] Roxburgh (1), vol. 3, pp. 26–7; Roxburgh (2), vol. 1, p. 240. It should be noted that some Indian scientists think that *S. sinense* was developed independently in India (Assam) and China (see e.g. Venkatraman (1)).

[f] See Watts (1), vol. 6, pt, 2, pp. 52–5 for a history of *S. sinense* in India during the 19th century.

[g] Wray (1), p. 12.

[h] Deerr (1), pp. 23–4.

[i] *Ibid.*, p. 24.

[j] For mosaic disease see Abbott (1), Martin, Abbott & Hughes (1), vols. 1 and 2 is the standard reference work for sugarcane diseases.

[k] Earle (1), p. 114 and Dodds (2), p. 23.

[l] Prinsen Geerligs (1), pp. 290–2.

[1] 和三盆 [2] 香川(縣) [3] 德島(縣)

known as Kavangire. As noted above, Kavangire was assumed to be a mutant form of Uba, from which it was only distinguished with great difficulty.[a] It played a minor role in Argentinian agriculture, but in 1920 ten tons of seed cane were shipped to Puerto Rico where mosaic disease was devastating the crop.[b] The virtual immunity of the clone Kavangire soon brought the disease under control and stabilised the Puerto Rican sugar industry.[c] During the 1920s a similar situation prevailed in Jamaica where large areas 'had to grow Uba extensively' to combat mosaic.[d]

S. sinense has been used extensively in modern breeding programmes, but with little success.[e] On the world scene, the Chinese contribution resided in providing large-scale commerical clones for south and mid coastal China, South-East Asia, Taiwan, Japan, Madeira and Natal for a very long period of time. Nonetheless, we must place equal importance on stabilising the mosaic epiphytotic in the sugar industries of Natal and Puerto Rico.

(6) *S. officinarum* in China

The inhabitants of New Guinea, island Melanesia and Polynesia used *S. officinarum* as a chewing cane. It may have moved towards South-East Asia at the time of the Austronesian expansions into the South Seas 3,500 years ago and from there filtered into China, probably before the Han dynasty, but this remains within the realms of pure speculation. However, documentary evidence indicated that *S. officinarum* was the major chewing cane south of the Nan-Ling ranges and lower latitudes of central China from the +7th century (see Fig. 20). Its use prior to this time, and as a sugar producer, awaits further research. The number of clones available remained very limited for two reasons. First, there is good evidence that only a small number of clones dispersed from the centre of origin in New Guinea.[f] Second, new clones were unlikely to be bred in China due to poor flowering.

Evidence suggests that a red and a white clone entered Asia from the Indonesian area. In India, the *Caraka Saṃhitā* recorded a white and a red-to-black cane at the time of Chirst, and these were presumably the red, and one of the white clones, that survived to be documented by Roxburgh in the early 19th century.[g] The +9th-century Muslim writer Abū Hanīfa Ad-Dīnawarī mentioned white,

[a] Rosenfeld (1), p. 155.
[b] *Ibid.*, p. 154.
[c] Chardon (1), p. 16.
[d] Innes (1), p. 350.
[e] G. Arceneaux, in a study of the pedigrees of cultivars throughout the world, has shown that *S. sinense* has had very little impact on sugarcane breeding (see Arceneaux (1), p. 85).
[f] Rumpf and de Loureiro, both accurate observers, recorded only a handful of clones in Indonesia (Rumphius (1)) and Cochin China (de Loureiro (1)) respectively.
[g] The *Caraka Saṃhitā* quoted from Deerr (1), p. 15. Dark red clones many vary in colour with the environment from red through purple to black. Roxburgh (2), vol. 1, p. 237, listed under *S. officinarum* two pale clones, Puri and Kullooa, and Kajooli, red.



Fig. 20. A clone of *Saccharum officinarum* L. (Badila) cultivated for chewing in Taiwan during the 1980s; Christian Daniels orig. photograph.

yellow and black clones on the east African coast.[a] In the Indonesian archipelago Rumpf described several clones including white, yellow, red and striped ones in his *Herbarium Amboinense* which he first completed in +1687.[b] Later Father Joannis de Loureiro in his *Flora Cochinchinensis* of +1790 listed three clones under *S. officinarum* including *rubrum*, 'stalks; short, thick, red, very juicy, internodes compressed', *elephantinum* 'stalks: very thick, red, long, less sweet, internodes compressed', and *alba* now under *S. sinense*.[c]

In China, *khun-lun chê*[2,1] was the first *S. officinarum* clone to be identified continuously in the sources. It appeared initially in the *Shih Liao Pên Tshao* of c. +670 which merely described it as red in colour.[d] It was mentioned as a red-to-purple-to-black coloured cane in virtually every pharmacopoeia until the

[a] Abū Hanīfa Ad-Dīnawari wrote the *Kītab en Nabat* c. +895, see Berthier (1), p. 293. Citations of this book included in the work of Ibn al-Beithar mentioned white, yellow and black clones, see Leclerc (1), 25, p. 383. Deerr (1), p. 18 incorrectly gave the location as the Barbary coast.

[b] Rumphius (1), vol. 5, p. 187.

[c] de Loureiro (1), vol. 1, p. 52.

[d] *Shih Liao Pên Tshao* quoted in the *PTKM*, p. 1889.

[1] 崑崙蔗

19th century.[a] The 1811 gazetteer for Lei-Chou prefecture in southern coastal Kuang-Tung remarked:[b]

One sort, called *khun-lun chê*[2] and known locally as *wu-chiao chê*[2,1] [literally crows feet cane], has large [stalks] of one *tshun* [3cm] diameter which contain abundant juice and have algorific properties (*hsing han*[2]) and can be up to five or six *chhih* [1.6–1.9cm] in height with internodes over two *tshun* [6cm] long. The rind may be either red or purple.

Kuwabara Jitsuzō[3] wrote that the term *khun-lun*[4] referred to an ancient country somewhere between Canton and Ceylon, and he noted that according to Chinese sources the people from this country were black skinned. The importation into China of *khun-lun* negro slaves was documented from the +4th century, and seems to have continued until the Thang dynasty at least.[c] It is not clear whether the word *khun-lun chê*[2] originated from this sugarcane having been initially brought from the country called *khun-lun* by the agency of man, or simply because it had a black rind.[d]

In 1848, an European observer, Charles Rondot, recorded a red cane in China and equated it with the *rubrum* of de Loureiro and the violet cane of Batavia.[e] The common red-to-violet cane of Batavia appeared in the European literature as Black Cheribon (Fig. 21),[f] and I believe the equation of *khun-lun chê*[2] with Black Cheribon to be a reasonable hypothesis. *Khun-lun chê*[2] was used for chewing, and Chinese sources frequently proclaimed it unsuitable for sugar production.[g] The experience of Chinese sugarcane growers in Java may provide the explanation for this claim. Gonsalves divulged that around 1800 to 1810 the Chinese discontinued the cultivation of Black Cheribon (*khun-lun chê*[2]) in Java for the following reasons.[h]

[a] Some red clones such as *khun-lun chê*[2] vary in colour with age, environment and amount of trash. They can range from red to purple to black; this is purely an environmental effect and the variant colours are not reproducible clonally. It is interesting to note that in the Ryūkyū Kingdom and Satsuma the characters for *khun-lun chê*[2] were read *Murasaki Satō* which literally means purple sugar and that it was used for making sugar (see *Shoshū Meibutsu Shi* under the Satsuma and Ryūkyū heading).

[b] 1811 *Lei-Chou FC*, ch. 2, pp. 51b–52a. The first reference to *wu-chiao chê*[2,1] that I have been able to find appeared in a +17th-century gazetteer for Hsu-Wen[6] county, which was administratively attached to Lei-Chou prefecture, see the entry for sugarcane in the +1687 *Hsü-Wên HC* under the subheading *wu chhan chih kuo chih chhan*[7].

[c] Kuwabara (1), pp. 61–2. This position regarding the colour association has been put in detail in Vol. 4, pt 3, p. 459, fn. e.

[d] The term *khun-lun* can refer to two different geographical locations; to the mountain ranges bordering on Tibet to the west of China, or to a country in South or South-East Asia. Mazumdar ((1), p. 69) suggested that *khun-lun* cane was associated with the western regional location and could be connected with the introduction of *Saccharum officinarum* from India via Central Asia. However, I argue that the colour association of *khun lun* with sugarcane indicated a relationship with the region to the south of China.

[e] Rondot (1), p. 201.

[f] Deerr (1), p. 21, gave the history of Black Cheribon and noted that a clone Red Preanger can only be separated from it on minute differences in the hair groups on the buds. This was another example of local mutation.

[g] The *TSP*, p. 3a commented that *khun-lun chê*[2] was only good for chewing, and the *PTKM*, p. 1889 specifically stated that it was unsuitable for making sugar.

[h] Gonsalves (1), p. 361.

[1] 烏脚蔗 [2] 性寒 [3] 桑原隲藏 [4] 崑崙 [5] 烏脚蔗
[6] 徐聞縣 [7] 物產志果之產



Fig. 21. *Saccharum officinarum* L. This photograph shows a field of Black Cheribon in Java in the late 19th century. In the text I show that Black Cheribon was most probably identical with the clone known to the Chinese as *khun-lun ché*; from Krüger (1), pl. 4, opposite p. 268.

The Chinese planters at that time had no efficient means and machinery to press the hard cane sufficiently. All their mills were imperfectly made of stones, and driven by buffaloes, and this may be the reason why the black cane was abandoned, and other kinds planted, which were called the white sorts. Indeed, when the black cane had passed through the stone mills, it was only pressed flat, and had to pass through two or three times, and even then was not sufficiently pressed. Nor could stone mills stand the hardness of the cane.

The hard rind would give difficulty to any pressing equipment and the unsuitability of *khun-lun chê*[2] for crushing was clearly the factor which contributed to its unpopularity. *Thieh chê*[2,1], or literally, iron cane, an apt description of a hard rind appeared in 19th-century gazetteers for Hainan island. It was dark brown in colour, and undoubtedly as synonym for *khun-lun chê*[2,a]. *Hei chê*[2,2] or literally, black cane, a chewing cane, also mentioned in a mid-19th-century gazetteer for Hainan, may be yet another appellation for *khun-lun chê*[2,b]. With chewing, the hard rind can be peeled off with the teeth to reveal the soft interior. *Hung chê*[2,3] (red cane), another variant name of *khun-lun chê*[2], was the only other *S. officinarum* name to be consistently mentioned over a period of time in the source materials as a chewing cane.[c] As it was red in colour, it may on occasions, have been the *elephantinum* of Loureiro.

Surprisingly no white coloured *S. officinarum* clones were specifically documented until the +16th century, expecially as white mutant clones of Black Cheribon have been found elsewhere. In section 'Sugarcane species in the period −200 to +670' we showed that it was not possible to differentiate whether *S. officinarum* or *S. sinense* was present. However, 'stalks like bamboo' which were mentioned often could be descriptive of a green *S. officinarum*. After +670, the dearth of green clones could be due to the fact that most of the texts were pharmacopoeias, and red clones were regarded as more effective in medicine and religion in South-East Asia and the Pacific. Such preferences may have encouraged pharmaceutical naturalists to reject white clones as unsuitable for medicine.[d] Alternatively, since most of the pharmacopoeias were written north of the Nan-Ling ranges, outside the area of adaption of the less hardy white clones, it may merely reflect their absence. Prior to the advent of hybrid varieties, Black Cheribon (*khun-lun chê*[2]) was one of the most adaptable *S. officinarum* clones

[a] 1820 *Chhêng-Mai HC* 10/7a and 1878 *Ting-An HC*, ch. 1, *wu-chhan*, p. 8b. For the colour of *thieh chê*[2] see Chalmers (2), p. 503.

[b] 1858 *Wên-Chhang HC*, ch. 2, p. 5a.

[c] *Hung chê* was equated with *khun-lun chê*[2] in the *TSP* of c. +1154, p. 3a and the *PTKM* of +1596, p. 1889.

[d] For example, the sugarcanes listed by Crevost and Lemarié (1), pp. 340–7 for medicinal value in French Indochina were red/black in colour, *mia thouc* (Tonkin), *ampou khmau* and *ampou leac* (Cambodia). In Malaya, Burkill (1), p. 1939 lists a purple-brown clone, *tebu gagak* as more effective than other canes for treatment of a number of diseases and specifically used in ceremonies and magic. Berding and Koike (1), pp. 112–13 records red-leaved, red stalk clones used exclusively for medicine in New Guinea. In China *khun-lun chê*[2] was specifically listed as a medicine, and the stalks were even used as a splint for mending broken bones, see *KTHT*, p. 689.

[1] 鐵蔗 [2] 黑蔗 [3] 紅蔗

known in the world, figuring as a commercial clone in temperate climates such as Louisiana.[a]

From the +17th century writers regularly listed white *S. officinarum* clones in non-medical literature such as the local gazetteers. For instance the +1686 gazetteer for Tsêng Chhêng county[1] in the Pearl river delta of Kuang-Tung province reported.[b]

> Sugarcane (*kan*[1] *chê*[2]): there are two colours, red and white. In addition there is bamboo cane (*chu chê*[2]) which can be boiled [to make] sugar.

The +1687 gazetteer for Yang-Chhun county[2] in Chhao-Chhing prefecture[3] of the same province mentioned three types of sugarcane: a red one, a white one and a white bamboo cane, and added that bamboo cane was also known as wax cane (*la chê*[2]).[c] The 1821 edition of the same gazetteer listed white sugarcane (*pai-kan chê*[2,4]) and bamboo cane as the two sugar-making clones.[d] More importantly the *Kuang-Tung Hsin Yü* of +1700 disclosed:[e]

> The most precious sugarcane is called snow cane (*hsüeh chê*[2,5]). It has large [stalks] with a diameter of two *tshun* [6 cm] and is one *chang* [3.17 m] in height with sparse internodes. It is exceptionally brittle by nature and must be propped up by a tree [i.e. a pole] otherwise it will break. It is what the *Shih Shuo*[6] described as 'Fu-Nan cane'[7] which has three internodes per *chang* [2.45 m, which is clearly a gross exaggeration or a mistake], wilts under full sunlight (*chien jih chi hsiao*[8]) and breaks when blown by the wind'. The flavour is especially excellent and it is eaten to quench thirst, but cannot be obtained in great quantities. The one that is commonly used at present is termed white cane (*pai chê*[2,9]). If ten stalks are eaten, heat will entirely be removed from the diaphragm. The purple one is known as *khun-lun chê*[2], and can be used as a splint for broken arms to enable the bone to join again. It is also called medicinal cane (*yao chê*[2,10]).

I suggest that snow cane (*hsüeh chê*[2]) could have been the *elephantinum* of de Loureiro on the basis of the large diameter[f] and references to it deriving from Fu-Nan in the Vietnam/Cambodia region.[g] The white cane (*pai chê*[2]) could be a white mutant of *khun-lun chê*[2], which was the *rubrum* of de Loureiro.

S. officinarum is still used extensively for chewing in modern China and Tai-

[a] Deerr (1), p. 22.
[b] +1686 *Tsêng-Chhêng HC*, ch. 4, p. 36b.
[c] +1687 *Yang-Chhun HC*, ch. 14, p. 10b.
[d] 1821 *Yang-Chhun HC*, ch. 1, p. 46a.
[e] *KTHY*, p. 689.
[f] Twice that of the average *S. officinarum* clone.
[g] The elephant cane does not seem to have been grown extensively in China proper, probably due to its brittle nature. It was most probably the Fu-Nan cane with the so-called three joints every *chang* that was presented to the Chinese court as tribute in +285 (*NFTMC*, shang, p. 5a). Elephant cane was transferred to the West in the late 19th century where its abnormally great diameter was confirmed in the report of G. S. Jenman, Government Botanist of British Guiana, see Jenman (1), p. 195. Deerr ((2), p. 59) was in error in claiming that this cane obtained its name because it was fodder for elephants and not from its enormous size.

[1] 增城縣 [2] 陽春縣 [3] 肇慶府 [4] 白甘蔗 [5] 雪蔗
[6] 世說 [7] 扶南蔗 [8] 見日即消 [9] 白蔗 [10] 藥蔗

wan. Clones such as Badila, introduced from New Guinea in the 20th century, are very popular. Chewing canes were discussed as a food above (pp. 55–59).

(7) The Concept of 'Varieties' in Sugarcane East and West

Earlier we noted that observers in China during the first millennium divided the sugarcane, *S. sinense*, into thick bamboo cane, *chu chê*[2], to the south of the Nan-Ling ranges, and into thinner miscanthus cane, *ti chê*[2], to their north (Figs. 22 and 23). They even noticed patches of bamboo cane on the rich river banks to the north of these ranges, and when cultivation moved onto infertile hills to the south of them, miscanthus cane appeared. Daniels & Daniels erroneously saw in these different names and descriptions a genetic difference between *S. sinense* and *S. barberi*, when in fact they only indicated an interaction of the *S. sinense* genotype with environment (see Daniels & Daniels (2)). The Chinese merely described the appearance of the phenotype of *S. sinense* by the descriptive epithets bamboo cane or miscanthus cane. To 20th-century observers, it appeared inconceivable that they could have thought this way.

Let us now turn to the West. Conventional wisdom held that only one clone, Creole, existed in the New World and Europe before the Dutch and French introduced the clone Otaheite from Batavia and Mauritius respectively in the later half of the +18th century.[a] Creole was said to have been the sole introduction from India via Persia and the Mediterranean. Daniels & Roach have shown that this may be incorrect as two clones illustrated in the +17th- and +18th-century literature appear to differ in internode shape (see Daniels & Roach (1)). First, de Chélus in his *Histoire Naturelle du Cacao et du Sucre* of +1719 illustrated a thick cane with tumescent internodes.[b] This was apparently the 'Creole' which Fleischmann and Deerr drew pictures of later.[c] Second, Earle described another 'Creole', cylindrical and with slender internodes.[d] This was presumably the cane illustrated by the German scientist Georg Marcgraf (Margrav) in his work included in the *Historia Naturalis Braziliae* of +1648 (Fig. 24), and by Albert Eckout in his painting of +1640 which clearly depicted cylindrical stalks.[e] Carl Sauer has also challenged the 'one Creole hypothesis' on the basis of thick sugarcanes described by Zuazo in +16th-century Hispaniola and reports by Labat in the late +17th-century Caribbean.[f] It is highly probable that

[a] Deerr (1), p. 19.
[b] de Chélus (1), p. 150, pl. 2.
[c] Fleischmann (1), fig. 18 and Deerr (2), pl. 1.
[d] Earle (1), p. 63.
[e] Piso & Margrav (1), Margrav, liber 2, p. 84. Georg Marcgraf of Liebstadt (+1610 to +1644), was educated at Rostock and Leiden, and died from fever in Angola at the age of thirty-four and at the height of his powers. C. R. Boxer wrote, 'A modern American scientist has remarked that if he had lived to publish more of his work he might well have become the greatest naturalist since Aristotle.' See Boxer (2), p. 150. For Eckout see Hemming (1), pl. 13.
[f] Sauer (2), p. 208.



Fig. 22. *Saccharum sinense* Roxb. from a 19th-century Japanese Pharmacopoeia. the *Honzō Zufu*, *kan* 68, pp. 17b–18a by Iwasaki Tsunemasa. It is a more accurate drawing than the usual pre-20th-century East Asian illustrations. For a more traditional Japanese illustration see Fig. 23.



Fig. 23. *Saccharum sinense* Roxb. from the *Satō Seisaku Ki*, p. 2a, of +1797 by Kimura Yoshiyuki. The artist has exaggerated the flaring of the leaf at the base which is somewhat characteristic of this species. At the bottom there are cane setts ready for planting with eyes in the correct position.

there was more than one medium-to-thick clone in the New World during the early +18th century.

When we turn to the wider European scene, confusion understandably arose over clones for the concept of genotype was a recent, 20th-century development in the West. The founder of modern taxonomic botany, Linnaeus (Carl von Linné), remarked in his *Philosophia Botanica* of +1751:[a]

[a] See Mayr (1), p. 288 and pp. 640–1 for the citation and a history of the concept of variety.

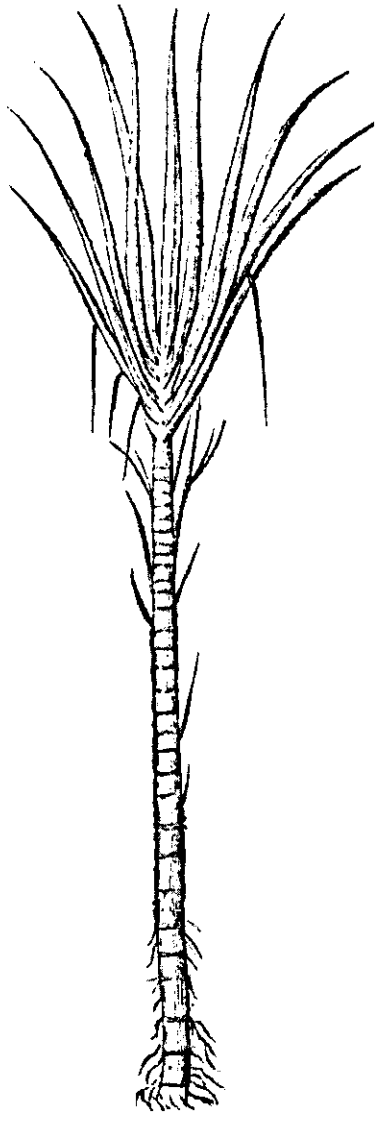


Fig. 24. Sugarcane in Brazil as represented in Piso & Margrav in their *Historia Naturalis Braziliae* of +1648, p. 83.

There are as many varieties as there are different plants produced from the seed of the same species. A variety is a plant changed by an accidental cause: climate, soil, temperature, winds etc. A variety consequently reverts to its original condition when the soil is changed.

Europeans evidently were no further advanced in their thinking on genotype and environment than the Chinese in the +18th century. This problem of the identity of a genotype separate from the environment was not solved until the 20th century, as has been so entertainingly told by Ernst Mayr. The rudiments

of an understanding of genotype seem to have emerged in China and the West during the late +18th century. Concerning China, we have noted previously that Rumpf recorded that the Chinese distinguished two groups of sugarcanes *tecsia* and *camsia*, which we now recognise as *S. sinense* and *S. officinarum* respectively. The time depth of this concept remains unknown, but it does indicate the first step towards the understanding of genotype. In the West, with the advent of clones with coloured stalks, there was a recognition of discrete clones. However this did not extend understanding of genotype very far, for we find one of the foremost scientists of the age, Alexander von Humboldt, philosophising after the introduction of the clone 'Otaheiti' to the West Indies and Latin America, at the end of the +18th century:[a]

> The important question which here arises, whether the sugar-cane of Otaheiti, when removed from its indigenous soil, will not gradually degenerate and merge into the common sugar-cane, has been decided in the negative.

Von Humboldt's understanding of genotype apparently was not any better than that of Linnaeus.

Ancient Indian medical literature of the *Caraka Saṃhitā* (+100) and the *Suśruta Saṃhitā* (+300) mentioned sugarcane varieties or clones; the *Caraka* recorded a white and a purple coloured cane, while the *Suśruta* listed twelve clone names.[b] In the +9th century the Muslim botanist Abū Hanīfa Ad-Dīnawarī writing on the plants of east Africa spoke of white, yellow and black clones.[c]

We can conclude that individual clones were recognised early in India and some parts of the Islamic world, as these areas had clones with coloured stalks, as well as clones of obviously different species *S. officinarum* and *S. barberi*. But we do not know to what extent the Indians and Muslims understood genotype and environment. Daniels & Daniels discussed evidence from the *Aṅguttara Nikāya* to show that Indian Buddhists did have a potentially better understanding of these matters than Europeans.[d]

> ... the Buddha discusses right views. He says that just as a nimb seed or a bitter pumpkin when planted, even under good conditions, gives bitterness and unpleasant taste, so a man with perverted views will always produce unpleasant and distasteful acts. Similarly when sugarcane, rice or grapes are planted under varying conditions they always give products of sweetness, pleasantness and delicious flavour. So a man with right views always performs deeds that lead to happiness. In both cases, the bitter and the

[a] Humboldt (3), p. 25.

[b] For dating of *Caraka* at +1st to +2nd century, see Basham (1), p. 500. Two clones were mentioned in the *Caraka Saṃhitā*, a purple cane (*Ikshu, Krishna ikshu* or *Vamsaka*) and a white cane called *Paundra* or *Paundraka*, see Deerr (1), p. 15. According to Basham, the *Suśrutā* was of c. +4th century. The *Suśrutā Saṃhitā* listed twelve clones, see Deerr (1), p. 16. Some of these were *Saccharum barberi* clones.

[c] Abū Hanīfa Ad-Dīnawarī wrote the *Kitābu n Nabadt* c. +895 which mentioned white, yellow and black clones, see Berthier (1), p. 293. Deerr ((1), p. 18) mistakenly recorded the location as the Barbary coast.

[d] Slightly revised from Daniels & Daniels (2), p. 52–3. The Pāli Buddhist scriptures were collected in the *Tripitaka* or three baskets, the *Vinaya* (rules), *Sutta* (doctrine), and *Abhidhamma* (elaboration on *Sutta*). The *Aṅguttara Nikāya* was one of the four sections (*nikāya*) of the *Sutta Pitaka*.

sweet, the Buddha asks the cause of these characteristics in the plant that does not vary with the environment. He answers himself that it is in the nature of the seed.

It took the Western world until the 20th century to reach the clear concept of genotype and environment implicit in this text.[a]

(8) Western Botany and Sugarcane in China

Western botany did not commence with Linnaeus. It is common knowledge that a handful of outstanding works preceded the *Species Plantarum* of +1753 that revolutionised our way of classifying and naming plants. The *Herbarium Amboinense* of Georg Rumpf completed in +1687, but not published until the +1740s was one such work.[b] Sugarcane appeared as *Arundo saccharifera*, a name coined by Caspar Bauhin in his *Theatri Botanici* +1623 (Fig. 25).[c] Rumpf described three 'species' of Javan clones. The first two were called *alba* and *rubrum* or *fusca* and the third was distinguished by thin stalks:[d]

> In China, the third species of cane is mostly grown. It has very thin stalks and rind. They call it *Tecsia*, from *Tec*, that is to say bamboo. They only use it to make sugar. All other thicker canes are called *Camsia*, which is better pronounced *Gamsia* [*kan chê*]. *Tecsia* is scarcely an inch thick and is usually yellowish like the clone *Boeloe Swangi* which is very soft and brittle.

This was the first mention of bamboo cane, and hence *S. sinense*, in a European work and sections of this citation appear without attribution in many later publications.

Sugarcane was one of the original Linnean species appearing in his *Species Plantarum* as *Saccharum officinarum*.[e] It is fairly certain that Linnaeus included the future *S. sinense* under the conspectus of *S. officinarum* as it has been shown that Linnaeus was probably familiar with the *Herbarium Amboinense*.[f] The Chinese connection with Linnaeus was very close indeed. Peter Osbeck (+1723 to +1805), a pupil of Linnaeus, went to China as a chaplain on a Swedish East

[a] For the history of concepts of genotype and environment refer to Mayr (1), pp. 781ff and the quotation from Linnaeus given above.

[b] Georg Everhard Rumpf (Rumphius) (+1627 to +1702) went to the East Indies as a cadet of the Dutch East India Company in +1652 after a period as a midshipman on their boats. He rose to the position of Chief Merchant at Amboina in +1662 and convinced the Company that he should work full time on the *Herbarium Amboinense* which he completed in +1687. Rumpf's misfortunes were salutory to lesser men, he went blind in +1670, lost his wife Sussana 'his first mate and helpmeet' in an earthquake in +1674, and all the illustrations were burnt in the great fire of Amboina in +1687. On sending the manuscript, fortunately copied beforehand, to Holland in +1690, it was lost at sea and did not arrive complete until +1697. It remained on the shelf until it was edited and published between +1741 and +1750 by John Burman, Professor of Botany at the University of Amsterdam. Each page was split with the Dutch text of Rumpf on the right and the Latin translation of Burman on the left. See de Wit (1).

[c] Rumphius (1), vol. 5, p. 188 and Bauhin (1), p. 18.

[d] Rumphius (1), vol. 5, p. 188.

[e] Linnaeus (13), p. 54.

[f] Grassl (6), p. 870.



Fig. 25. *Saccharum officinarum* L. from the *Herbarium Amboinense* of Georg Rumpf completed in +1687, see Rumphius (1), vol. 5, p. 191. This is one of the great works of pre-Linnean botany and Rumpf knew the plant as *Arundo saccharifera*. This plate is the first accurate botanical drawing of sugarcane which shows a flowering specimen. The plant on the left is recorded as typical (clone name unknown), while the one on the right is an atypical clone called Rottangam.

Indiaman in +1750 and spent four months in Canton.[a] Bretschneider remarked that it is 'generally believed that Osbeck placed all his Chinese collections in the hands of Linnaeus, but Linnaeus determined and described only a small portion of Osbeck's Chinese plants'.[b] Osbeck's diary published in +1757, listed *Saccharum chinensis* and *Saccharum pluviatile*. John Reinhold Forster translated Osbeck's account into English in +1771 without the diaries under the title, *A Voyage to China and the East Indies*, which included the following passage:[c]

SUGARCANE (*Saccharum officinarum*), the Chinese name of which is *Kee-a*, was planted in rows between the hills. The plants were tied together, to prevent their bending to the ground. They were above a fathom long, but I could neither at that time nor afterwards discover its flowers.[d] China therefore is not the place whence it originally came from, which must be a far warmer climate.

Forster appended a *Faunula and Flora Sinensis* to his combined translations in which he listed: 1. *Saccharum officinarum* and 2. *Saccharum pluviatile*.[e] Notice that *Saccharum chinensis* mentioned above had already been equated with *Saccharum officinarum* by Forster. *S. pluviatile* was most probably the large reed *Miscanthus sinensis* Anderss. Forster also translated and included in his book, Charles Gustavus Eckeberg's *A Short Account of the Chinese Husbandry*. Eckeberg served as a captain on several ships of the Swedish East India Company making eight voyages to China between +1743 and +1771, and brought the first living tea plant to Europe, which reached Linnaeus on 3 October +1763. His account was the first substantial mention of Chinese sugarcane to include details on its cultivation and crushing in a European work.[f] Eckeberg was accompanied on his +1766 voyage by his cousin, Andreas Sparrmann, who left on record that they collected *Arundo saccharifera* (sugarcane) near Canton on 24 August +1766.[g] As sugarcane flowers after December at this latitude, it must have been vegetative material.[h]

As remarked earlier, Joannes de Louriero described three clones of *S. officinarum* for Indo-China in his *Flora Cochinchinensis* of +1790. One of these, variety *album*, has been recognised as *S. sinense* by its Cochinese name *miá lau* and description. In 1819, William Roxburgh coined the binomial *Saccharum sinense* in his Plants of the Coast of Coromandel to describe the Chinese sugarcanes and he included a plate of the inflorescence (see. Fig. 18).[i] He based his descrip-

[a] Bretschneider (10), p. 58.
[b] *Ibid.*, p. 59.
[c] Osbeck (1), vol. 1, p. 350.
[d] Osbeck sojourned at Whampoa, near Canton, from 25 Aug. +1751 to 6 Jan. +1752. *S. officinarum* and *S. sinense* would flower in late January, so it is not surprising that he did not see any flowers.
[e] Osbeck (1), vol. 2, pp. 342–3.
[f] *Ibid.*, pp. 296–7.
[g] Bretschneider (10), p. 62.
[h] See p. 167 fn. e.
[i] William Roxburgh (+1751 to +1815) an Assistant Surgeon in the East India Company at Madras from +1776, was sent to Samulcottah (300 miles NNE of Madras on the Coromandel coast) to found an experimental garden for economic plants in +1781. In +1793 he was transferred to the Calcutta Botanic Gardens as

(*cont.*)

tion on a clone introduced into the Calcutta Botanic Garden from Canton in +1796. *S. sinense* subsequently appeared as *S. sinensis* in all subsequent editions of Roxburgh's *Flora Indica*.[a] Roxburgh's description included a report on cultivation and manufacture at Canton compiled from a letter written in +1796 by a correspondent, Mr. A. Duncan, which accompanied the clone introduced from China. Roxburgh related his knowledge of Chinese sugarcane in the following fashion:[b]

This new species, for such it appears to me, was introduced from China into the Botanic Garden at Calcutta, at the close of the year 1796; with the hopes of finding it in some respects better than the common cane cultivated over India, and hitherto it has promised considerable advantage; particularly as the cane is so solid and hard, as to resist the forceps of the white-ants and the teeth of the Jackal, two great enemies to our East Indian sugar plantations. At the same time it bears drought much better than the sorts in general cultivation. Lasts (ratoons) so as to be a profitable crop even to the third year; (while the common cane of India must be renewed every year); and yields juice of a richer quality. It seems to be the sort employed over China for making their sugar from, as appears from the following extract of a letter from Mr. A. Duncan, the Surgeon to the Factory at Canton, to Richard Hall Esq. President, &c. Select Committee, dated Canton, 26th October 1796, which accompanied this cane from China; explaining the mode of cultivation, and manufacturing the sugar in the Province of Canton.

'Of sugarcanes, two sorts are cultivated in the Province of Canton; one which is small [in diameter], compact and highly saccharine, is manufactured into sugar, whereas the other of a larger size, and looser texture, is generally cut into joints, and ate by the natives, either raw, or gently heated ...'.

Here Duncan plainly described *S. sinense* and *S. officinarum*.

Charles Rondot reported the presence of many clones of sugarcane in China

Footnotes to page 169 (*cont.*)

Superintendent. Since +1791 he had participated in a project initiated by the death of John Gerard Koenig (+1728 to +1785). Koenig was naturalist and surgeon at the Danish mission at Tranquebar on the Coromandel coast and bequeathed his botanical collection and MSS to Sir Joseph Banks on his death in +1785. Patrick Russell, East India Company's chief botanist in the Carnatic at the time, proposed to Banks that the East India Company be approached to publish a flora based on the Koenig papers. This project took a number of years to mature and by the time the East India Company approved it, Roxburgh had become the leading botanist and he instituted the project in +1791, using his own observations as the Koenig papers proved unsuitable. This resulted in *Plants of the Coast of Coromandel* in 12 parts, each with 25 plates, all fully coloured and arranged in 5 volumes published between +1795 and 1820, see Sealy (1). Sugarcane appeared in vol. 3, pp. 26–8, and *S. sinense* was illustrated in pl. 232.

[a] Roxburgh left India sick in 1813 with the manuscript of *Flora Indica* complete. He was to holiday in South Africa to regain his health, but his condition deteriorated and he proceeded to Scotland and died in Edinburgh in 1815. His friend William Carey, the orientalist, missionary and printer, published an incomplete version in two volumes, in 1820 and 1824, which included some corrections by Nathaniel Wallich, his successor at the Calcutta Botanical Gardens. This edition was usually known as the Carey edition. Two of Roxburgh's sons commissioned Carey to publish a complete edition of *Flora Indica* without Wallich's additions. This was printed at the famous Serampore mission press in 1832, and was usually known as the Serampore edition. Charles Baron Clark issued a third edition complete in one volume in 1874, this was commonly known as the CBC edition, see Sealy (1).

[b] Roxburgh (1), vol, 3, p. 27. Note that words in round brackets are in the original and words in square brackets are additions by the present author.

and discussed two in particular.[a] First, a red cane, which he equated with the violet cane of Batavia, and the *Saccharum rubrum* of de Loureiro, which was certainly *khun-lun chê*. Second, the *Saccharum album* of de Loureiro, which Rondot equated with the *Mia-laou* of Cochinchina and the sugarcane of Brazil. *Mia-laou* (*miá lau*) from Thailand, and Uba of Brazil were typical *S. sinense* clones. This last clone of Rondot was the one most usually cultivated in China.[b] Rondot also mentioned two clones in Korea, a thick green clone and a thin yellow one.[c] In 1869 Stanislas Julien and Paul Champion listed four clones of sugarcane in China. Their account was obviously based on the *Thang Shuang Phu* of the mid +12th century, though they included some additional descriptive information, such as the zig-zag stalks of miscanthus cane (*ti chê*), not furnished in the original.[d]

Karl Ritter (+1779 to +1859), one of the founders of modern geography, delivered a brilliant, comprehensive paper on sugarcane to the Berlin Academy in 1839.[e] He included large sections on China for which he obtained his information from a manuscript translation of the *Pên Tshao Kang Mu* by a certain Professor Schott. Virtually all the Chinese information included in de Candolle's *Origin of Cultivated Plants* and Noel Deerr's *History of Sugar* derived from this source,[f] and needless to say these two latter works have been cited as secondary sources by hordes of recent scholars. Bretschneider in his celebrated *Botanicon Sinicum* and in his earlier work of 1870, *On the Study and Value of Chinese Botanical Works*, curiously gave only minimal coverage of *S. officinarum*.[g]

From the time of Roxburgh's *Plants of the Coast of Coromandel* of 1819 to Hackel in 1889, all major botanists regarded *S. sinense* as a valid species.[h] Hackel reduced *S. sinense* to *S. officinarum*,[i] and his classification has exerted such tremendous influence that even today some general taxonomic botanists would not accept *S. sinense* as valid. In 1925 Jeswiet revised Hackel's *Saccharum*, and recognised three species: *S. officinarum* for the thick tropical sugarcanes, *S. sinense* Roxb. for the Chinese sugarcanes and a new species *S. barberi* Jesw. for the Indian. He named *S. barberi* after Barber who had described five horticultural groups in India.[j] One of the five groups, Pansahi, was identical with *S. sinense* and reputedly dated in India from Roxburgh's introduction of the clone in +1796.[k]

[a] Rondot (1), p. 201.

[b] These observations of Rondot support the hypothesis on dispersal of *S. sinense* presented above.

[c] Rondot (1), p. 201. Apart from Rondot and the *Honchō Shokkan* of +1697 by Hitomi Hitsudai, which mentioned the introduction of sugarcane into Japan from Korea, we have not been able to find any other evidence for sugarcane in Korea. For the *Honchō Shokkan* reference see Shimada Isao (1), vol. 2, p. 139.

[d] Julien & Champion (1), pp. 204–5.

[e] Ritter (1).

[f] Deerr (1), p. 39.

[g] Bretschneider (1), vol. 3, pp. 438–9 and Bretschneider (6), pp. 45–7.

[h] Hackel (1), p. 113 and for other botanists see Kunth (1), vol. 1, p. 474; Steudel (1), p. 406; Miquel (1), vol. 3, p. 511.

[i] Hackel (1), P. 113.

[j] Jeswiet (1), and Barber (2) and (3).

[k] Roxburgh (2), vol. 1, p. 240. As remarked earlier some Indian scientists such as Venkatraman (1) think that *S. sinense* was developed independently in India (Assam) and China.

The division into *S. officinarum*, *S. sinense* and *S. barberi* has been accepted by the International Society of Sugarcane Technologists and by virtually all practising sugarcane breeders.[a]

Edmund von Lippmann the renowned chemist, historian of alchemy and sugar technologist wrote the first comprehensive history of sugar, *Geschichte des Zuckers*, in 1890 with a revised and expanded edition in 1929 which was updated in 1934 and 1938. The *Geschichte* exerted considerable influence on Latin American scholars through a Portuguese two-volume translation published in Brazil between 1941 and 1942. It contained considerable information relevant to China scattered throughout the text, with some detail in chapter seven on China, and chapter fourteen on the Orient.

Noel Deerr's two-volume *History of Sugar*, published in 1949 and 1950, remains the standard history in English, being widely and uncritically quoted. It has a chapter four on China which relied heavily on Ritter (1).

Baxa & Bruhns published *Zucker im Leben der Völker* in 1967 which was most valuable for a large number of well-chosen illustrations. Baxa and Bruhns relied heavily on von Lippmann and Deerr. Unfortunately, two of the illustrations on China have seriously misleading captions. First, on p. 218, there was an illustration of two, three-roller, vertical, animal-driven mills with huts for boiling the juice, with captions indicating a provenance in China at the end of the 19th century, but with no authority apart from the Bettimann Archive, New York. This drawing was actually executed from observation in the Ryūkyū islands by Francis Hawks, a member of Commodore Perry's Japanese expedition, appearing in his narrative of the expedition.[b] It has nothing to do with China. Second, the so-called 'mill around 1900' on p. 219, was from page 89 of the 17th-century narrative of Nieuhof on the Dutch legation to China from +1655 to +1657.[c]

The most recent history of sugar, *The Sugar Cane Industry* by J. H. Galloway, was published in 1989. This study was not fashioned on the grand, comprehensive scale of von Lippmann and Deerr, but has the more modest objectives of examining the cultivation and manufacture of sugarcane in the tropics, with the exclusion of consumption and refining. Galloway is particularly strong on the social and economic problems associated with technological change down the ages, but the section on China in chapter eight, is rudimentary.

(9) Sugarcane Illustrations

One of the earliest known illustrations of sugarcane came from the Islamic world, appearing in an anonymous Arabic manuscript, probably dating from

[a] Daniels & Roach (2).

[b] Hawks (1), p. 313. This illustration was used by Galloway ((4), p. 207) in error as evidence for the primacy of three-roller milling in China.

[c] Nieuhof (2).



Fig. 26. An illustration of a sugarcane clone from the Islamic World in a manuscript fragment of Ibn al-Baitār's *Book of Simples* of c. +14th century. This is the first known illustration of sugarcane flowering; Bibliothèque Nationale, Paris, MS arabe 2771, fol. 184r (taken from reproduction in Watson A. M. (1), p. 25).

the +14th century. The manuscript concerning natural history, bound together with a fragment of Ibn al-Baitār's *Book of Simples*, is in the possession of the Bibliothèque Nationale in Paris.[a] This illustration showed a stool of cane with eight stalks, all flowering, and was a reasonably accurate drawing of a clone with erect leaves and clinging trash (see Fig. 26).[b]

The first illustration in European literature occurred in the *Cosmographia Universalis* published by the German geographer Sebastian Münster at Basel in +1544.[c] The striking feature of this drawing was the correct portrayal of the shot buds on the nodes with one bud on a different side of each node (see Fig.

[a] Watson, Andrew (1), p. 25.
[b] These are characteristics of clone Creole, thought to be available in the Mediterranean at the time.
[c] Reproduced in Baxa & Bruhns (1), p. 29.

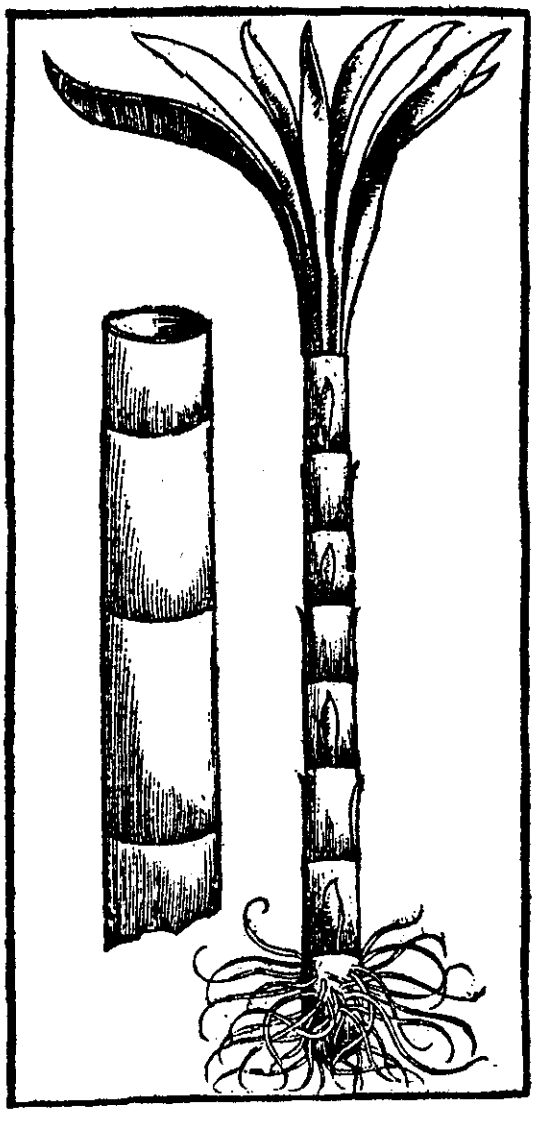


Fig. 27. The earliest European representation of sugarcane in the *Cosmographia Universalis* of +1544 by Sebastian Münster; through Baxa & Bruhns (1), p. 29.

27). A more competent drawing appeared in the *Historia Naturalis Braziliae* of +1648 by Guilielm Piso and Georg Margrav, which depicted a thick sugarcane stalk stripped of leaves with nodes close together (see Fig. 24).[a]

The first known Chinese drawing appeared in the *Chêng Lei Pei-Yung Pên Tshao*[1] of +1249, but the artist only showed the root of the sugarcane plant (see Fig. 28).[b] The interest of this illustration was that the stalk seems to have been

[a] Piso & Margrav (1), p. 83.

[b] *Chêng Lei Pei-Yung Pên Tshao*, ch. 23, p. 24a.

[1] 證類備用本草



Fig. 28. The earliest Chinese illustration of sugarcane appearing in the +1523 edition of the *Chêng Lei Pei-Yung Pên Tshao*, ch. 23, p. 27b which was first printed in +1249. The top of the stalk can be interpreted in two ways. It could either represent leaves as shown in Fig. 29, or a broken stalk as suggested in the illustration in Li (12), p. 57.



Fig. 29. Sugarcane in the +1628 illustrated edition of the *Pên Tshao Mêng Chhüan*, ch. 7, p. 12a, which was first printed in +1565. This drawing is patently inaccurate because two leaves are attached to each internode, and in addition there is a lack of proportion between the size of the leaves and the stalk.

broken off rather than cut with a cane knife. Though cane knives were mentioned in the *Thang Shuang Phu*[1] of c. +1154, it is difficult to determine the extent of their use.[a] Needless to say, the availability of an effective cane-cutting knife was one precondition for the development of the production of sugar on a large scale. The *Pên Tshao Kang Mu*[2] of +1596 illustrated a standing stalk of sugarcane with roots and tops but no leaves.

[a] *TSP*, p. 4a.

[1] 糖霜譜 [2] 本草綱目



Fig. 30. *Saccharum officinarum* L. from the *Chih Wu Ming Shih Thu Khao* of 1848, Wu Chhi-Chün (*2*), ch. 32, p. 27a. The artist has captured the essential feature of *S. officinarum*, the thickness of the stalks, but he was evidently drawing from memory as the buds are not placed on opposite sides of the stalk.

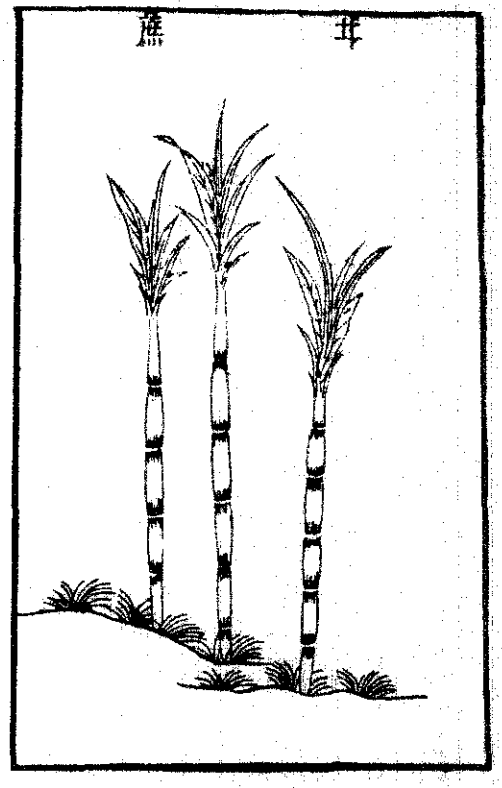


Fig. 31. Sugarcane as depicted in the *San Tsai Thu Hui* of +1609 *tsao-mu*, ch. 11, p. 27a. This is an idealised representation of *Saccharum officinarum* L., and as in Fig. 29 the leaf area is not in proportion to the size of the stalk. A similar illustration appeared in the *Shou Shih Thung Khao* of +1742.

Later Chinese illustrations were obviously executed by artists working true to their tradition, painting and drawing from recollection rather than from life. The +1628 enlarged and supplemented edition of the *Pên Tshao Mêng Chhüan*[1] has a sugarcane stalk with two leaves striking from the same node, which was needless to say botanically incorrect (Fig. 29).[a] Even the illustration in the *Chih Wu Ming Shih Thu Khao*[2] of +1848 depicted two node buds one above the other on the same side of the stalk (see Fig. 30).[b] Compare these Chinese illustrations with the superb botanical plate executed by David Blair and included in the *Medicinal Plants: Being Descriptions with Original Figures of the Principal Plants Employed in Medicine* of 1880 by Robert Bentley and Henry Trimen (see Fig. 17).[c] It

[a] *Pên Tshao Mêng Chhüan*, ch. 7, p. 12a.

[b] Wu Chhi-Chün (2), ch. 32, p. 37a.

[c] Bentley & Trimen (1), p. 298. Also for an excellent example of +18th-century drawing of sugarcane see Woodville (1), pl. 196.

[1] 本草蒙筌 [2] 植物名實圖攷

would seem that most Chinese illustrations of sugarcane were never accurate botanical reproductions, even when the written accounts in the same work provided reasonable descriptions.[a]

A fascinating feature of Chinese drawings of sugarcane was that they all illustrated thick noble canes, *Saccharum officinarum*, with short internodes that were utilised for chewing. A fine specimen was the drawing in the *San Tshai Thu Hui*[1] of +1609 (see Fig. 31).[b] The only illustration of a sugar-making *Saccharum sinense* clone, probably *chu chê*[2] (*chikusha* or *chikusho* in Japanese) or bamboo cane, occurred in the Japanese treatise on sugar making, the *Satō Seisaku Ki*[2] of +1797 by Kimura Yoshiyuki[3] (see Fig. 23),[c] which also depicted cane setts ready for planting.

(*d*) SUGARCANE AGRICULTURE

(1) Climate and Ethnic Origins of the Cultivators

As background knowledge for understanding early Chinese sugarcane agriculture we have to review two critical factors, climate and prehistory. South and central China are divided into two distinctive climatic and ethnographic zones by the massive Nan-Ling[4] mountains, the five ranges of Sung Ying-Hsing.[d] The warm tropical south inhabited by the Yüeh 'barbarians' prior to conquest by the Han Chinese around −214, and the temperate central Chinese region which Han Chinese settlers reached by −400.[e]

Helmut Blume has assembled modern climatic data on Chinese sugarcane areas and I reproduce his map in Fig. 32.[f] Blume displayed four climatic zones, of which zone I corresponds to our 'south of the ranges', and zone III is typical of north of the ranges. Higher yielding areas are shown by broken vertical lines on the map and actual data are given in his table 54. Cane yields per hectare in the provinces of Fukien, Kuang-Tung, Kuang-Hsi and Yunnan, all located south of the ranges, were on the average over 20 per cent higher in the early 1980s, than in the provinces north of the ranges. Data in his table 55 indicated about 15 per cent higher sucrose percentage cane in the south.[g] A complete climatic picture can be obtained by comparing Fig. 32 with Fig. 33, a precipitation map of China. The darker areas show rainfall above 1,500 mm,

[a] For an example from the early 20th century see Ho Kang-Tê (*1*), ch. 2, p. 10a.

[b] *San Tshai Thu Hui, Tshao Mu*, ch. 11, p. 27a. This drawing was later reproduced in the *Shou Shih Thung Khao*, ch. 66, p. 8b of +1746.

[c] *Satō Seisaku Ki*, p. 386.

[d] Sung Ying-Hsing, the author of the *Thien Kung Khai Wu* of +1637, was the first to point out in detail the effect on sugarcane agriculture of the different climate north and south of the ranges.

[e] Wang (1), p. 4.

[f] Blume (1), map 27, p. 238. Past climates and their effect on the cane growing areas are discussed below.

[g] Some high yields in zone II just north of the ranges, are due to higher rainfall.

[1] 三才圖會 [2] 砂糖製作記 [3] 木村喜之 [4] 南嶺

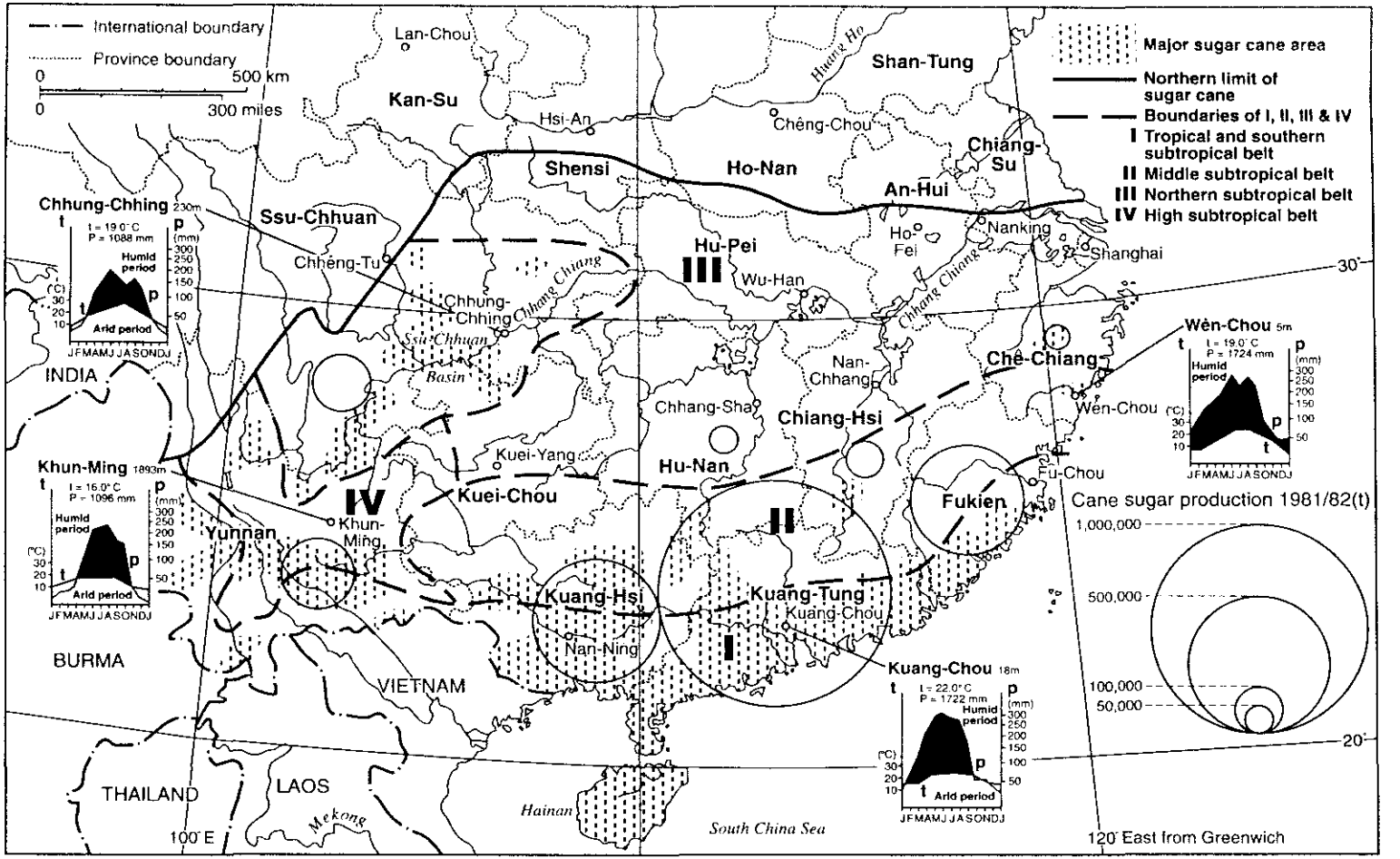


Fig. 32. A map of China showing the upper limits of sugarcane cultivation in the 20th century, along with the four major climatic zones; from Blume (1), p. 238, map 27.

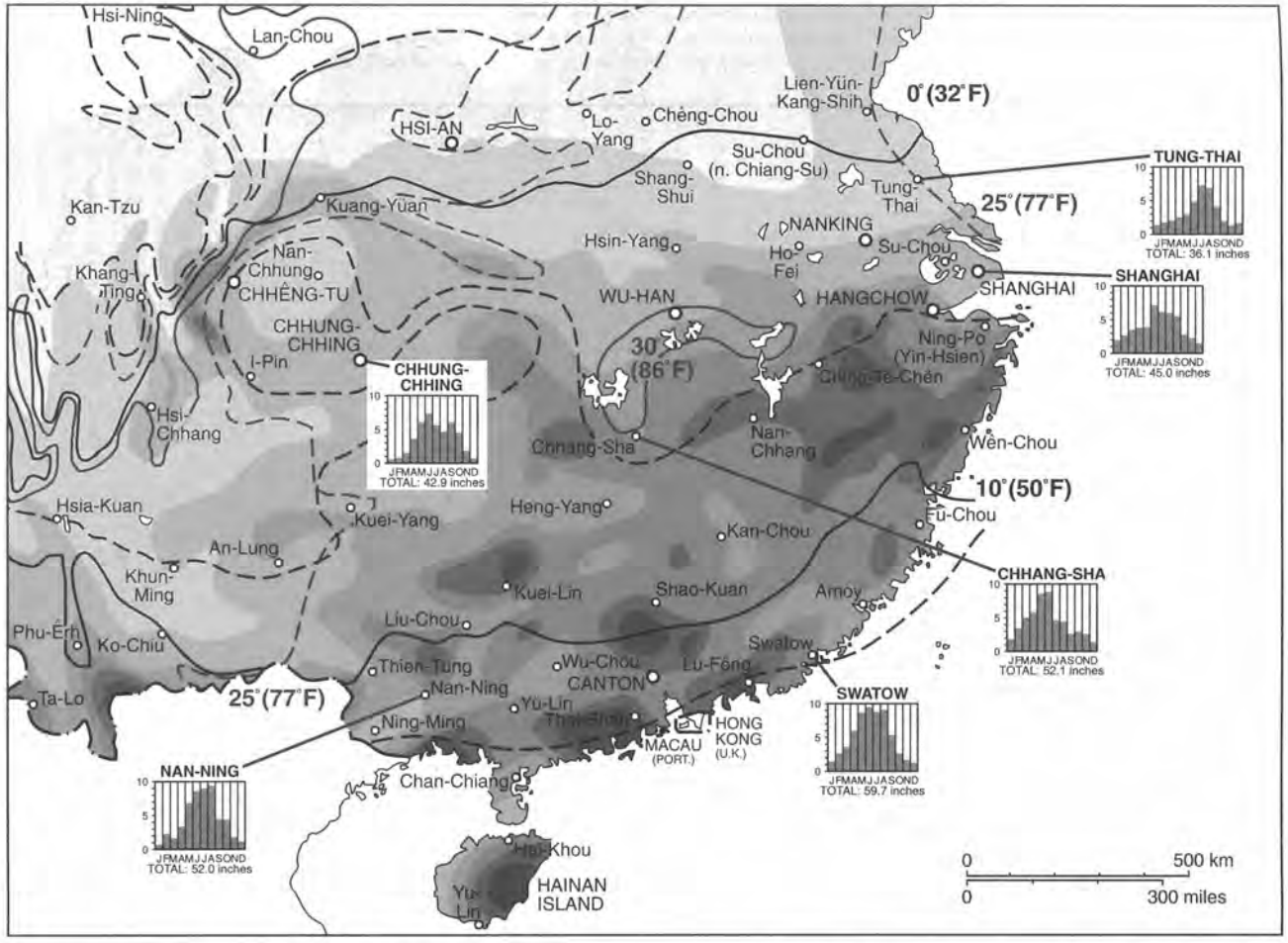


Fig. 33. A climatic map of China with darker areas indicating an annual precipitation over 1,500 mm (c. 60 inches). 1,500 mm is about the amount at which good commercial crops of sugarcane can be cultivated with natural rainfall. The smaller boxes for individual locations give an appreciation of the marked monsoonal distribution of rainfall. Deficits in spring and autumn are unfavourable for planting, but the winter deficits are most favourable for sugar accumulation and ease of harvesting; map modified from Geelan & Twitchett (1), p. 20.

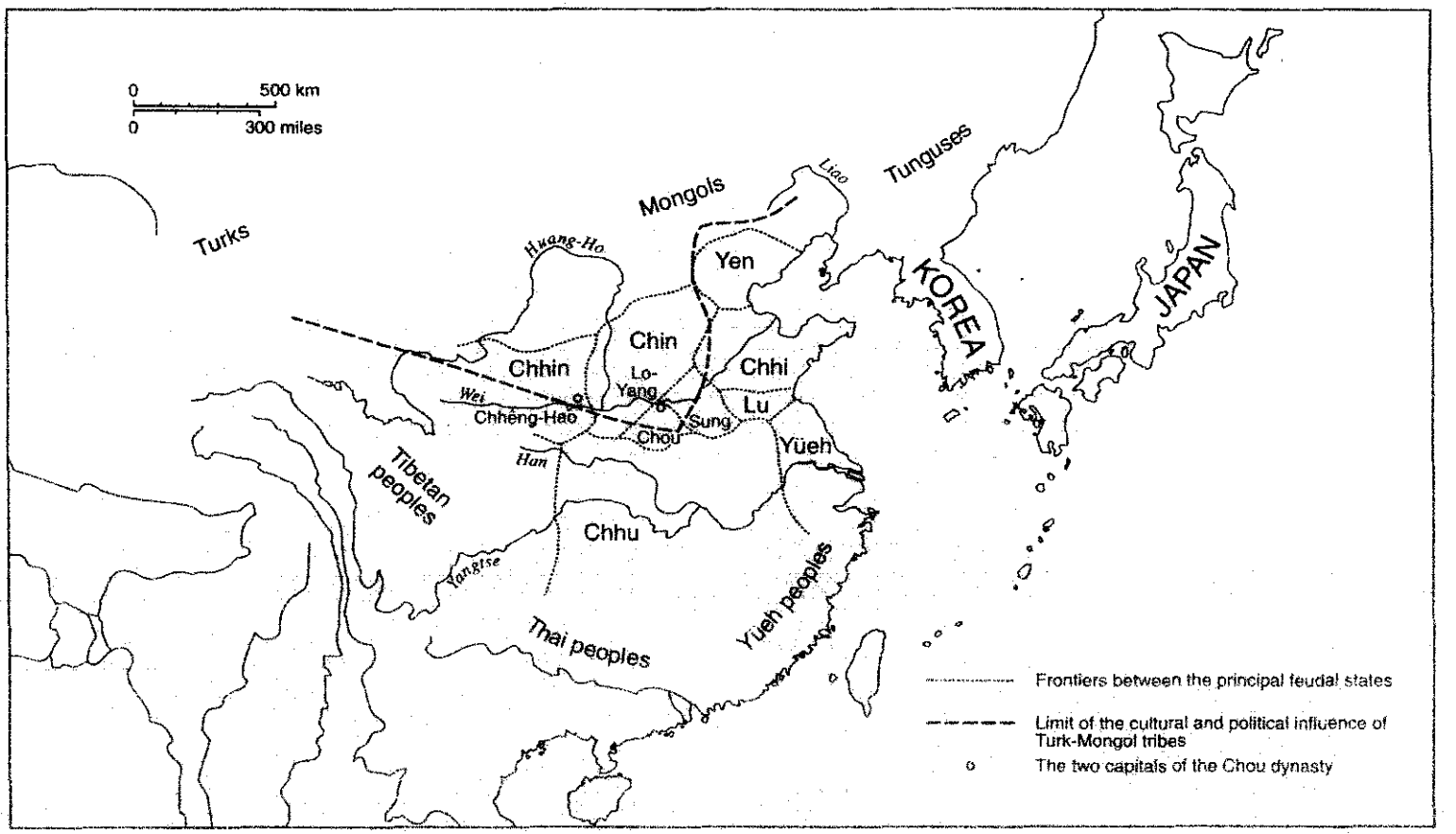


Fig. 34. A map of China showing the areas occupied by the southern 'barbarians', the Yüeh and Thai peoples, in the period just prior to the expansion of the Han Chinese into south China. The Yüeh occupied the lands that later became the major sugar-producing areas of China. Reference to Figs. 32 & 33 also indicates that these areas enjoyed the most favourable climate for sugar production; from Eberhard (9), p. 33, map 2.

which lies within the level at which rainfed sugarcane can be cultivated.[a] In summary, the areas south of the ranges give higher yields with a higher sugar content in cane. More specifically, the fact that cane yields in Ssu-Chhuan registered 50 per cent less than those obtained in Fukien, both recorded as sugar-producing regions since the +6th or +7th centuries at least,[b] highlights the climatic disadvantage that the colder northern growing areas have sustained over the centuries (for an explanation of the northern and southern zones, see p. 185). The main climatic difference affecting agriculture between the two areas is that north of the ranges cold weather and frosts shorten the growing and ripening period, and pose special problems such as availability of seed cane for planting. South of the ranges favourable temperatures provide a longer growing season. These demonstrated effects of climate require different agricultural strategies.

The tropical and sub-tropical zones I and II of Blume (1) approximate to the areas Eberhard assigned to the Yüeh, Thai and other 'barbarians' prior to −200 (see Fig. 34).[c] The areas north of the ranges had been absorbed into the Han Chinese sphere of influence for a considerable period before. In his discussion on the southern ethnic groups, Eberhard distinguished Liao, Yao, Thai and Yüeh (=Thai × Yao) 'each of which was a contributor in its own way to later "Chinese culture"'.[d] Schafer described the southern peoples and arrived at a different conclusion: 'the southern provinces of China are not truly Chinese even now. They are 'interior colonies' of non-Chinese peoples, exploited and oppressed for more than two thousand years by the Chinese settlers and agents of their northern government. The most extreme case is Kuang-Hsi Province, recently recognised as the "Kwangsi-Chuang Autonomous Region"'.[e] The variation in emphasis between these scholars highlights the cultural and ethnic differences extending over time between north and south of the ranges.[f] Eberhard *et al.* recorded these ethnic differences extending westward into Yunnan and southern Ssu-Chhuan. More recent research on the Yüeh and 'sinicisation' has stressed autonomous development of elements of civilisation in the south and their eventual contribution to Chinese culture.[g]

[a] It is generally accepted that sugarcane cannot be grown with rainfeeding below 1200 mm, see Blackburn (1), pp. 70–1, Blume (1), p. 45.

[b] *Hsin Hsiu Pên Tshao* quoted in *PTKM* p. 1889.

[c] Eberhard (9), p. 33, map 2.

[d] Eberhard (9). p. 6. In this work Eberhard condensed his more detailed studies collected in Eberhard (2). Herold Wiens summarised Eberhard's earlier work in Wiens (3) and provided additional sources in his chapter 2. The wide range of tribes, literally hundreds are involved, confuses the reader, so it is better to rely on Eberhard. Fitzgerald (11), pp. 1–78 provides a summary of Chinese expansion and southern peoples extending into South-East Asia.

[e] Schafer (16), p. 15. Also see *ibid.* pp. 1–78, which provides a more 'poetic' description of the southern peoples.

[f] See Wang (1), p. 8 for political groupings south of the ranges c. −200 and the four commanderies set up in the conquered territories.

[g] See Keightley (4) and especially Meacham (3).

This is undoubtedly true, but we retain the term 'sinicisation' to denote the active promotion of Han Chinese culture and technology.

We need not consider individually the southern ethnic groups, known collectively as Yüeh[1],[a] but suffice it to say that they included tribes such as the Yao[2] who cultivated mixed crops by slash-and-burn methods (*shê*)[3] in the valleys and hills, and groups such as the Thai who grew monoculture rice and mixed crop gardens on valley floors and in delta areas.[b] Sugarcane played a part in both situations. Chang Hêng[4] (+78 to +139) in his Han dynasty *Fu on the Southern Capital* gave a revealing description of a rice and mixed crop farm which included sugarcane in a Tung Yüeh[5] coastal area:[c]

> From the streams
> Tunnels have been bored that lead the rushing current
> Flowing into these rice fields,
> Where channels and ditches link like arteries,
> Dikes and embankments web with one another;
> Dawn clouds need not rise up
> The stored waters find their way alone,
> And when the sluices are opened, they drain away,
> So that the fields are now flooded, now dry again,
> And the winter rice, the summer wheat
> Ripens each in its proper season.
> In the broad meadows
> Are mulberry, lacquer trees, hemp, and ramie,
> Beans, wheat, millet, and panicled millet,
> A hundred grains, thick and luxuriant,
> Burgeoning, ripening.
> In garden plots
> Grow smartweed, fragrant grasses, turmeric,
> Sugar cane, ginger, garlic,
> Shepherd's purse, taro, and melons.

Historians of sugarcane have invariably insisted that sugarcane entered China during the –2nd century or later.[d] Tai Kuo-Hui, on the basis of a few scattered references in Chinese literature, followed Katō Shigeshi in plotting the

[a] Yüeh was a political division. The Yüeh were not homogeneous ethnically, culturally or technologically. For convenience we will use the geographical divisions of the Yüeh outlined in Vol. 6, pt 1, p. 443: Tung Yüeh[5] (Chekiang and Chiang-Su), Min Yüeh[6] (Fukien), and Nan Yüeh[7] (Kuang-Tung, Kuang-Hsi and Vietnam). I follow the overall definition of the Yüeh by Meacham (2), p. 425: Yüeh denotes a sphere of indigenous peoples/cultures of the South well outside the influence of the central plains down to the Warring States or Han period (ca. 500BC–AD200).

[b] See Vol. 6, pt 2, p. 99 and Schafer (16), pp. 48–55.

[c] Watson, Burton (1), p. 7.

[d] For example see Deerr (1), vol. 1, p. 35; Laufer (1), p. 376; Katō Shigeshi (4), vol. 2, pp. 676–7. Katō followed de Candolle in regarding sugarcane as not being indigenous to China, but originating in the India/Indochina region.

[1] 越 [2] 瑤(族) [3] 畬 [4] 張衡 [5] 東越
[6] 閩越 [7] 南越

route of introduction: sugarcane moved north from Chiao-Chih, in present-day North Vietnam, through Kuang-Tung and Kuang-Hsi to Hu-Nan, from whence it reached Ssu-Chhuan on the one hand, and the lower Yangtse provinces of Chiang-Hsi and Chekiang on the other.[a] A more realistic hypothesis would hold that sugarcane emerged in Chinese literature at this time because this was when the Han Chinese conquered the Yüeh, and first became aware of southern crops and customs.

An examination of south Chinese prehistory supports the antiquity of sugarcane in this area. A growing body of evidence indicates that south China, Fukien and Taiwan in particular, were the 'homeland' of the Austronesian people who dispersed into Indonesia and Oceania about −5000.[b] Robert Blust (Blust (1)) has reconstructed cultural inventories of the 'homeland' and sugarcane features as one of the cultigens that the Austronesians took on their migration. This gives sugarcane an antiquity of at least −5000 and as such it would be a domesticate of neolithic cultures in the area. Meacham discussed these coastal neolithic cultures, and listed their domesticates as: 'tubers, fruit trees, hill-rice, tea, sugarcane, dyes etc.,' and suggested that these neolithic cultures were early Yüeh people.[c] In Vol. 6, pt 2, the origin of Chinese agriculture was discussed in general terms and the following scenarios were listed:[d]

1 diffusion from a nuclear area in the Near East and central Asia (ruled out on the basis of firm evidence from food crops)
2 diffusion from a nuclear area in the loess area in north China (shown to be untenable because of early dates for the domestication of rice in central China)
3 diffusion from South-East Asia (thought to be unlikely but had to be retained as a possibility)
4 development from local cultures
   (a) through the 'affluent forager' scenario in which foragers with abundant naturally occurring 'surpluses' in sea food, roots and fruits, are regarded as having had the leisure to develop agriculture[e]
   (b) through population pressures from rising sea levels that flooded adjacent Sunda land from −10000 to −6000[f]
   (c) through natural development of indigenous cultures.

[a] Tai (1), pp. 12–13 and Katō (4), vol. 2, p. 683.

[b] Eberhard (9) and Wiens (3) both record some of the groups as Austronesian. Recent researchers agree that there are no Austronesian-speaking people amongst the remnant tribes at the moment. There is considerable research effort in this area because south China is regarded as a possible 'home' of the Austronesian people who are the ancestors of the Indonesian and Oceanic peoples, see Bellwood (1), pp. 88, and Bellwood (2), pp. 111–16, pp. 204–45; Bellwood (3), pp. 214–16.

[c] Meacham (3), p. 158. See Institute of Archaeology (1), p. 28 which still sees a strong northern influence on the Neolithic cultures of south China, and claims that there was a big margin of error in carbon-14 dating for specimens found in south China limestone areas 'causing dates to be attributed to an earlier period'.

[d] Vol. 6, pt 2, pp. 27–47.

[e] Proposed by Sauer (3) in 1952, and more recently by Chang (8).

[f] Meacham (3), p. 154.

Domestication of local plants undoubtedly took place as the lichee (*Litchi chinensis* Sonn.) is indigenous to south China. In general terms, future research on diffusion scenarios will centre on whether humans introduced the concept of the domestication of plant crops, rather than the cultigens themselves. In the sugarcane context, an early introduction from South-East Asia cannot be completely ruled out, but from the Austronesian dispersal data it must have been an early Yüeh and pre-Yüeh cultigen.

The most significant expression of ethnic differences between the northern and southern zones from the agronomic point of view, was that the Yüeh, subsistence agriculturalists, did not engage in the commercial production of agricultural products.[a] The traditional produce of the south included rhinoceros horns, elephant tusks, tortoise shells, kingfisher feathers, pearls and fruits, articles gathered rather than grown.[b] Wheatley pointed out that the conscious 'sinicisation' of the Yüeh commencing in the Han dynasty included 'vaguely defined agricultural improvements,' and he attributed land reclamation in north Vietnam to Chinese leadership and technology. He also remarked that the plough shares found in archaeological sites were shares for spade ploughs rather than the Chinese mould board.[c] Spades would have been adequate for small-scale rice production, and we have no reason to believe that the Yüeh were anything but small-scale subsistence cultivators. Schafer has noted instances of 'agricultural extension' with Han Chinese lending ploughs to Yüeh in the Thang dynasty, and Wei Tan[1] teaching the barbarians of Jung-Chou[2] how to plough as late as +801 to +804.[d] The subsistence method of planting sugarcane on mounds in low-lying fields persisted until the late +18th century because it was good horticulture.[e] The usual scenario shows the assimilation of subsistence agriculturalists, the Yüeh, into Chinese culture as rice farmers, or mixed croppers over a period of about two thousand years. Early 'they adopted the new landlord–tenant relationship and land tenure system which replaced the earlier true feudalism of pre-imperial China'.[f] This has always seemed to me a gross oversimplification. Contrast this with the picture presented by Schafer, Wang Gungwu[3] and Wiens of a classic colonial 'us and them' situation, with the Yüeh being dragged into Han Chinese civilisation by an immigrant colonial elite. Superimposed on this were large injections of Han migrants from the north at various strategic times. I will not argue this situation further here, but

[a] Although 'sinicisation' commenced in the Han dynasty it was the Thang before any agricultural commodities at all were exported from south China, and the Sung before the production of significant quantities began, see Wang (1) for a comprehensive history of the southern trade.

[b] Wang (1), p. 8. Hemp cloth listed from Phan-Yü (near modern Canton) is the only sign of cottage industry.

[c] Wheatley (4), pp. 128, 141.

[d] Schafer (16), pp. 33, 60.

[e] Duncan described this practice near Canton during the +18th century, see Roxburgh (1), vol. 3, p. 27.

[f] See Fitzgerald (11), pp. 21–2; Tsukada (1).

[1] 韋丹 [2] 容州 [3] 王賡武

the fact remains that whatever the political situation during the period −221 to +960 covered by Wang Gungwu's study of commerce south of the ranges, Chinese sources failed to mention sugar as an article of trade. As demonstrated in (*b*), above, the trade in sugar appeared in the historical sources from the Sung and Yüan periods. At this time Fukien emerged as a centre of excellence in sugar production, and a large producer for the long-distance market. Fang Ta-Tshung[1] of the Southern Sung disapprovingly remarked:[a]

> Cane Sugar (*chê-thang*[2]) [production] consumes the paddy fields of Hsien-Yu county[3] [in Fukien], and we do not know how many tens of thousands of jars are transported to Chê-Huai[4] (Huai-Nan[5] and Liang-Chê[6]) each year. Sugarcane stubbornly obstructs [the use of] paddy fields [for growing rice].

During the Yüan, Marco Polo claimed Fukien as the largest producer of sugar in the world, and interestingly enough Fang's complaints about the expansion of sugar production during the Southern Sung supported this assertion.[b] As explained above, despite early beginnings, Kuang-Tung and Chiang-Hsi did not become major sugar-producing provinces until the +17th century when Fukienese peasants brought superior agricultural techniques and manufacturing technology to these areas. They expanded the area of land under sugarcane and in Chiang-Hsi rapidly monopolised the sugar trade. Chinese immigrants transferred these superior techniques overseas to the Philippines, Vietnam, Java, Taiwan, and elsewhere, a topic to which we will return later.

North of the ranges, sugarcane cultivation appeared in the literary record by the time of Thao Hung-Ching,[7] the +5th-century physician and alchemist. In addition, it rated a mention in the *Chhi Min Yao Shu* of c. +535. The import of sugar from Persia probably stimulated Chinese sugar cultivation in the Thang dynasty. Schafer established from tribute records that sugarcane was grown in central Ssu-Chhuan, northern Hu-Pei and coastal Chekiang by the Thang dynasty.[c] The evidence also indicated that starting *de novo*, traditional northern Chinese agriculture found application north of the ranges. As demonstrated below this became necessary to cope with a climate radically divergent from that of the south, and played a major role in determining the two different sets of sugarcane cultivation techniques that evolved in China.

Taking these climatic differences into consideration we will divide the major sugarcane areas in China, all of which lie below latitude 31° N, into northern and southern zones, which we sometimes also refer to as north and south of the ranges. The north encompasses zones II and III on the Blume map (Fig. 32), that lie within the region generally called central China, including

[a] *Thieh-An Chi*, ch. 21, p. 4b.
[b] Moule and Pelliot (1), p. 341.
[c] Schafer (13), p. 152.

[1] 方大琮 [2] 蔗糖 [3] 仙遊縣 [4] 浙淮 [5] 淮南
[6] 兩浙 [7] 陶弘景

Chiang-Hsi, Chiang-Su, Chekiang and Hu-Nan and the Ssu-Chhuan basin. All of these provinces were at one time or another significant sugar-producing centres. The south, which corresponds with zone I of the Blume map, includes most of coastal Fukien[a] and Kuang-Tung together with Kuang-Hsi and the islands of Hainan and Taiwan. It should be plain to the reader by now that the usage of the words north and south differs considerably from the conventional north–south division of agriculture given in Volume 6, part 2.

(2) Long-Term Climatic Variation in China

Sugarcane is very sensitive to temperature, with growth slowing down considerably at about 20°C, and finally ceasing at 16°C to 12°C depending on other conditions.[b] The longer-term temperature effects of climate were discussed in a general fashion in Vol. 6, pt 2.[c]

Temperatures remained very favourable from about +400 to the end of the Sung, after which they turned less favourable until the 20th century. The lowest point came about +1700, when on the other side of the world cold temperatures played a part in the demise of the English vineyards.[d] In the winter of +1683 the Thames froze over from London Bridge to Blackfriars Bridge and was turned into a vast fairground. This only occurred again in 1814.[e]

Favourable temperatures all through the Sui, Thang and Sung periods,[f] undoubtedly contributed to the expansion of sugarcane growing north of the ranges. The higher temperatures in the coastal areas also encouraged cultivation, and in Marco Polo's time Fu-Chou[1] in Fukien thrived as a centre of sugar manufacture, but by the 20th century sugar had ceased to be produced on the Min river[2] for commodity production.[g] Lower temperatures, as well as economic factors, may also have encouraged the demise of sugar manufacture on the Min.

One wonders whether the climatic low affecting production in the north did not prompt the expansion of sugarcane growing in the south during the +17th, +18th and 19th centuries. In Thang times Yang-Chou[3] in Chiang-Su (32°N) supplied the Chinese court with sugarcane for sugar making, and Yüeh-Chou[4] in Chekiang (30°N) made *shih-mi*[5] from sugarcane under Imperial order.[h]

[a] Fukien although geographically located in the southern zone was an early centre of northern zone agricultural methods and acted as a 'nuclear' area for the dispersal of new techniques in the southern zone and overseas.

[b] Alexander, Alex. Getchell (1), pp. 434–7.

[c] See Vol. 6, pt 2, pp. 23–5. The following discussion is based on Fig. 11 of Vol. 6, pt 2, a graph showing fluctuations of temperature in Europe and China from about −3000 to 1950.

[d] Lamb (2), p. 30.

[e] Braudel (2), vol. 1, p. 50.

[f] There was a slight reversal at one period during the Sung.

[g] See Tregear (3), map, 47 (a) for distribution of sugarcane in Fukien.

[h] *Hsin Thang Shu*, p. 6239 for Yang-Chou and *Hsü Kao Séng Chuan*, ch. 5, p. 7a for Yüeh-Chou.

[1] 福州 [2] 閩江 [3] 揚州 [4] 越州 [5] 石蜜

Sugar-producing districts of the lower Yangtse delta region listed in Thang pharmacopoeias ceased to be of significance after the Sung–Yüan period, when Fukien and Ssu-Chhuan eclipsed them.

(3) Sugarcane Agriculture in General

We have seen that sugarcane agriculture commenced north of the ranges in about the +5th century, but it was c. +1000 before the commodity production of sugar began in earnest in the south, as indicated in (*b*), above. Before proceeding with a detailed study of agriculture, we must first introduce the reader to some idiosyncrasies of the sugarcane plant, and to appreciate the Chinese experience, we must see how sugarcane agriculture evolved in India, the Islamic world and other cultural areas. With this background, Chinese sugarcane agriculture can be examined in detail.

(i) Sugarcane as an agricultural phenomenon

Some elementary knowledge of sugarcane morphology and its method of propagation is necessary to understand sugarcane agriculture. Sugarcane clones range from being non-flowering, to flowering profusely, and the flowering clones in turn, vary from being completely sterile, to setting large amounts of seed. When seeds are planted, they do not breed true to the clone; sugarcane is a heterozygous plant. Under favourable conditions natural germinations in the wild produce new clones from which pre-historic man selected better clones to replace those existing. Modern sugarcane breeders do this in a systematic manner in agricultural experiment stations.[a]

For normal sugarcane agriculture, setts must be planted from stalk cuttings. The stalk (see Fig. 35) is segmented into nodes and internodes, and at each node there is a bud, a ring of root eyes (primordia) around the stalk, and an intercalary meristem.[b] The three-eye sett shown in Fig. 35 is the usual planting unit. If we move to Fig. 36, we can see that, on planting, the eyes and root primordia germinate to form a shoot and sett roots respectively. The young plant grows from this base, and after a few weeks, tillering commences with underground eyes germinating from the primary shoot. Fig. 37 displays secondary, tertiary and later order shoots which subsequently form in the next three to four months.

Eyes and roots do not germinate in the above-ground section of stalks, because the growing point translocates an auxin down the stalk which inhibits their growth.[c] This top dominance persists when the stalks are cut, and if a

[a] Heinz (1).

[b] The meristem is capable of further growth. If a field of sugarcane is blown over, the growing point and leaf axis are restored to the vertical position, by the meristem at several nodes growing on the appropriate side.

[c] Blackburn (1), p. 149.

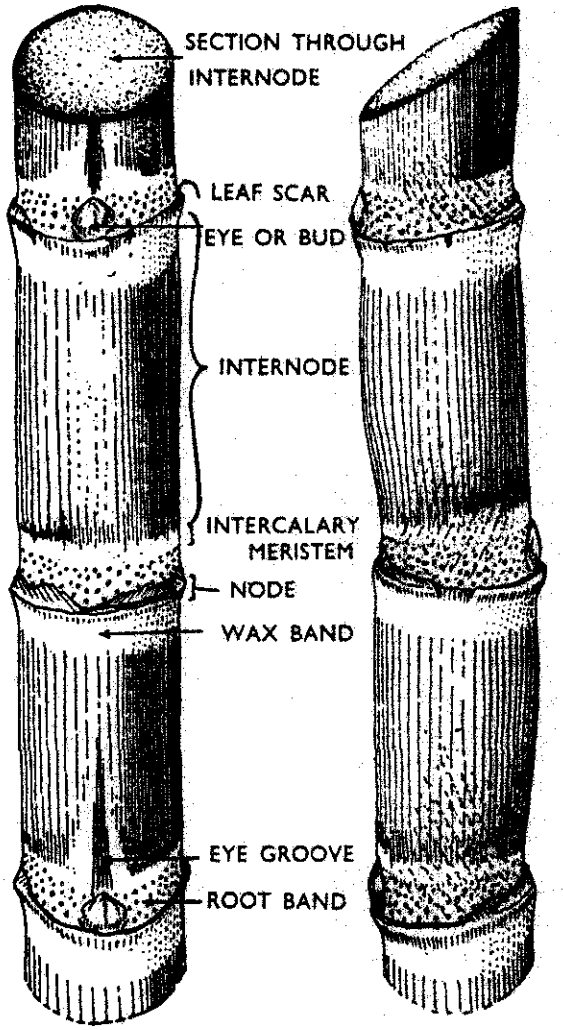


Fig. 35. A three-eye sett of sugarcane showing the structure of the sugarcane stalk. At each node there is one bud, rows of root primordia, and an intercalary meristem. The new shoot germinates from the eye and the sett roots from the root primordia. The intercalary meristem ('growth ring') can grow, and if sugarcane is blown over in high winds, it can expand on the affected side to re-position the growing point to vertical; from Martin, Abbot & Hughes (1), p. 17.

whole stalk is planted, only the top one or two buds will germinate. For this reason agriculturalists cut the stalks into setts, the usual configuration being three-eye setts, and occasionally two- or four-eye setts, but they use one-eye setts in seed beds for transplanting into the field. Another important fact about germination on planting, is that, when soil temperature falls below about 18°C on the average, setts will not germinate or germinate only very slowly; there are, however, significant clonal differences.[a] Therefore farmers in sub-tropical

[a] Humbert (1), pp. 101–2.

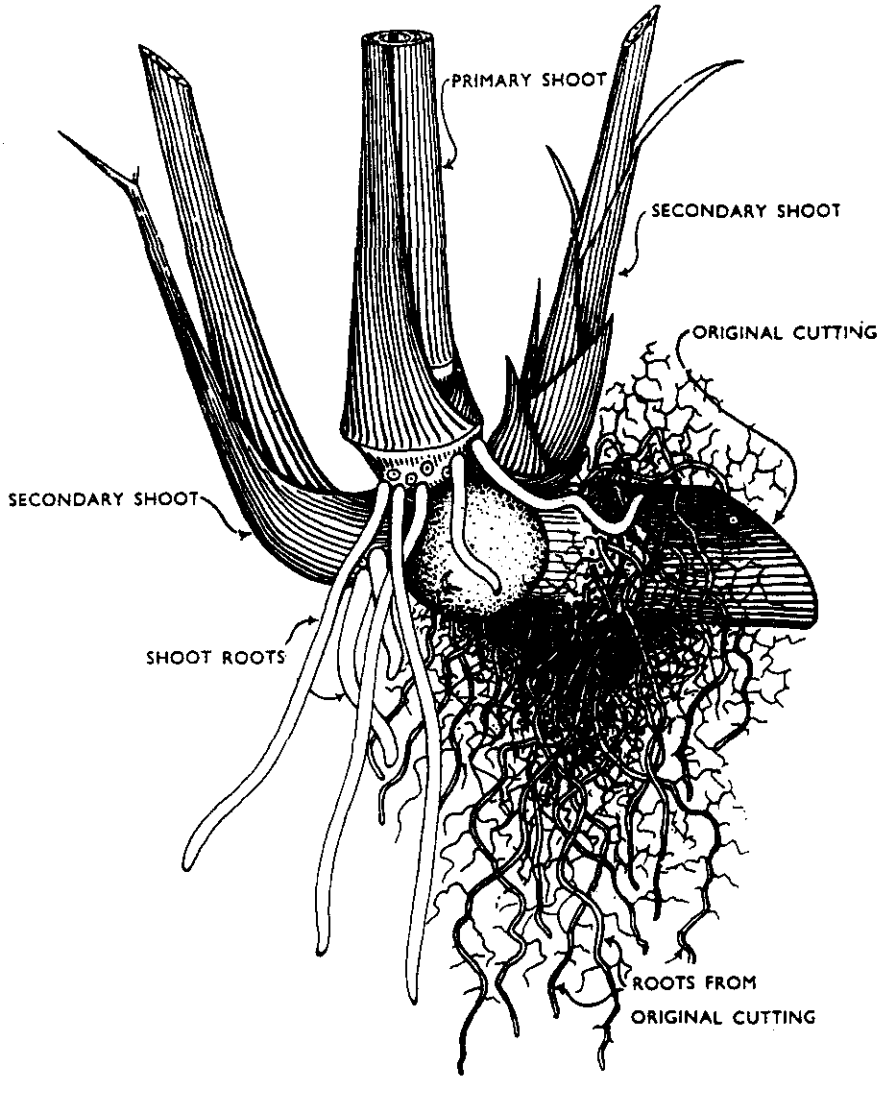


Fig. 36. A sett of sugarcane that has been planted and 'struck'. The primary shoot has germinated from a bud and roots appear from the original sett and secondary shoots from buds on the growing shoot; from Martin, Abbot & Hughes (1), p. 20.

situations have to carefully choose the time for planting in spring, and make special arrangements for seed cane if frosts have killed the buds in standing cane.[a] I will discuss this below in the Chinese situation.

The stool tillers heavily by about three to four months after planting. A full leaf canopy develops, and the leaves close in and completely shade the ground.

[a] In some temperate zone areas, cane farmers utilise the cold positively. Sugarcane is planted in autumn, the frost kills the germinating cane and it ratoons in the spring. This can result in poor stands that have to be 'supplied' with setts in spring. If the timing is right the seed remains dormant and does not germinate until the spring.

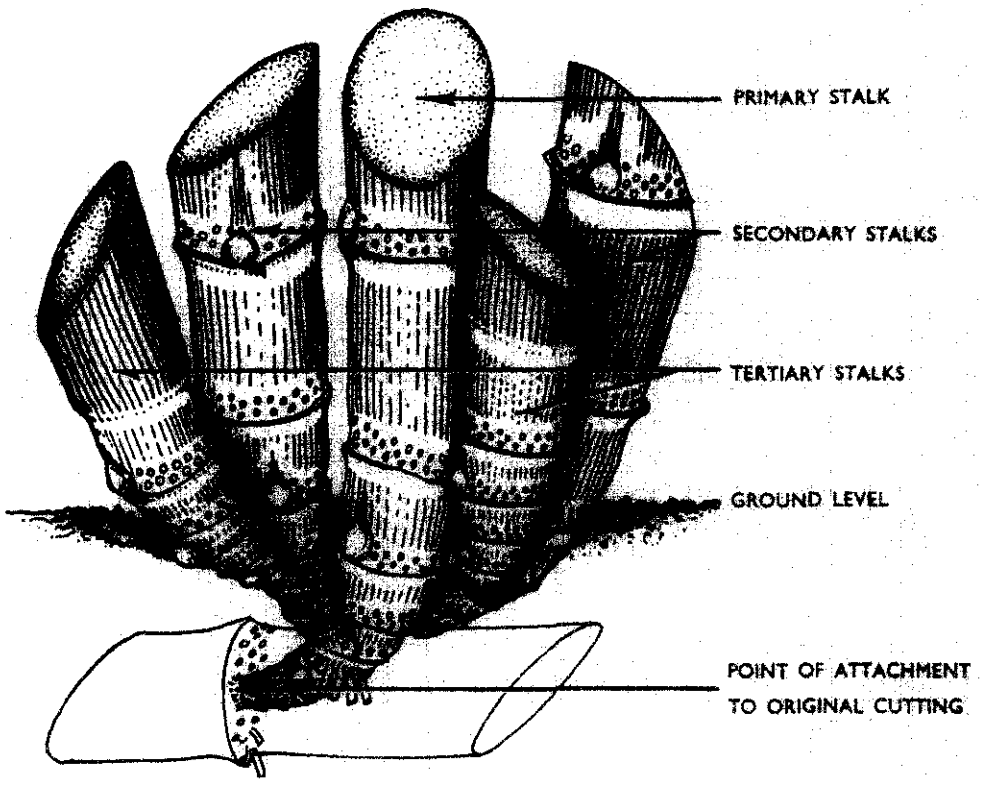


Fig. 37. This dissection of a stool of sugarcane shows how the plant tillers. The primary shoot has buds which 'strike' and the process continues with the second- and third-order shoots; from Martin, Abbot & Hughes (1), p. 18.

At this time, if there is adequate temperature and moisture, the tillers begin to elongate very rapidly in a boom growth phase. In most situations the cane attains two to four metres of stalk and is ready for harvest after a year.[a] In subtropical areas growth diminishes and ceases with the onset of winter, when the cane is only about nine months old. Sugarcane killed by frost or snow has to be harvested immediately.

After harvesting, the old root system dies, but the buds and root primordia of the rootstock will germinate and yield a new crop, as soon as weather conditions become favourable. In higher latitudes the chief determinant is adequate spring temperature. This procedure is called ratooning (from the Spanish *retoño*), and depending on soil type and conditions, up to three or more ratoons can be economical.[b]

[a] See review in Humbert (1), pp. 17–18.
[b] See Blackburn (1), pp. 158–61 for a discussion of 20th-century economics of ratooning.

(ii) Sugarcane agriculture in early India, the Islamic world, the New World and South-East Asia/Oceania

Before studying Chinese sugarcane agriculture in detail it is instructive to examine how other ancient cultures handled the problems involved. This will help to delineate the unique Chinese contribution to sugarcane agriculture.

Shifting agriculturalists of South-East Asia, Indonesia, Melanesia and Polynesia planted sugarcane in mixed gardens in pre-historic times. These gardens usually comprised a mixture of several cultigens, and the agriculturalists prepared the soil with digging sticks or hoes, and planted the cultigens on mounds or in holes 1–2 m apart depending on drainage arrangements. They tended the plants until maturity with digging sticks, hoes, hand-weeding etc.[a] In some situations, such as the New Guinea highlands, they utilised precisely these techniques to cultivate sugarcane as a monoculture on large areas of 'open field'.[b] At first sugarcane only found use as a plant for chewing; sugar production came later with the adoption of Indian and Chinese technology.

Sugarcane cultivation for making sugar seems to have first commenced in northern India. The earliest evidence appeared at the time of the Buddha about −500, and there are actual accounts of sugarcane fields and penalties for stealing sugarcane (Brahmins exempt) as early as −200 in the *Manusmṛti* (Laws of Manu).[c] Though we lack early accounts of sugarcane planting and cultivation methods, we do have the report of John Augustus Voelcker, who was in India from 1889 to 1891 on behalf of the British government to examine current methods of agriculture, and to recommend improvements. He found that the traditional procedure, still common, basically amounted to making a seed bed four to five inches deep by extensive scratch ploughing:[d]

> Next the field is levelled, and the cuttings of seed cane are scattered broadcast over the surface. The seed is the lightly covered over with soil. In consequence, the cane grows irregularly, and a jungle is formed; weeding cannot be properly done, and air and light cannot properly penetrate.

This was the traditional Indian method, and since it is difficult to imagine anything less complicated, we assume that it approximated to the early method of

[a] For south India see Watt (1), vol. 6, pt 2, p. 233; for Vietnam, Poivre (1), p. 107; for south China, Roxburgh (1), vol. 3, p. 27; for Hawaii, James Cook through Cushing (1), p. 18; for New Guinea, Steensberg (1), pp. 71–85.

[b] Brookfield (1).

[c] Bühler (1), p. 313

[d] Voelcker (1), p. 248. This statement of Voelcker's was supported by Barber (6), p. 393. Voelcker and Barber may be regarded as disinterested observers, while the official reports from district officers, such as those reproduced in Watt (1), vol. 6, pt 2, tended to stress the most advanced methods applied in 19th-century Indian agriculture to demonstrate the success of their own efforts. Wray, writing in the 1840s (Wray (1), p. 147) recorded some areas of north India where peasants planted sugarcane in drills positioned close together, but made no attempt to keep them straight. This amounted to broadcast planting.

cultivation in north India. In summary, flat land agriculture with the crop sown by broadcasting seed, characterised the Indian method; water was simply flooded on to the flat fields if irrigation proved necessary.

To the west of India, the Sassanian Empire produced sugar probably by c. +600, although sugarcane may have been grown as an oasis, fruit crop for sometime prior to this date.[a] The delay of almost a millennium in the transfer of sugar technology from India to Persia probably derived from their radically different climates. North India enjoys a summer monsoonal climate with 500 to 1500 mm precipitation, while Persia has a predominantly winter rainfall of 150 to 300 mm. Sugarcane needs total irrigation west of India as there is no rain during the hot summer months, the boom growth period of the sugarcane plant. No sources exist for Sassanian sugarcane agriculture; however, Thorkild Jacobsen has reconstructed the methods of irrigated, cereal agriculture from the Sumerian *Georgica* composed during the third dynasty of Ur about −2100. According to Jacobsen the fields were ploughed with a scratch plough and harrowed, large clots being broken up with tools such as mattocks and hoes. Grain seed was sown in furrows through a funnel attachment on the scratch plough. The plantings were sub-surface irrigated from furrows running lengthwise through the field and parallel to the seed furrows; these irrigation furrows were fed from transverse supply furrows.[b] As these are precisely the methods followed later for sugarcane planting in the Arabic world, it is reasonable to hypothesise their use for sugarcane in Sassanian Persia.

After the Muslim conquest of +640, the Arabs transferred sugarcane agriculture westwards across the southern Mediterranean, and to Spain by the +10th century.[c] The Mediterranean climate resembles that of Persia with a winter rainfall of about 500 mm and a consequent large deficit during the summer boom growth period. Medieval agronomists and encyclopaedists did a good job documenting Arabic sugarcane agriculture, and Deerr provided extensive translations from the Hispano-Islamic agronomist Ibn-al-'Awwām (second half of +12th century) in Spain, and the historian al-Maqrīzī (+1364 to +1442) in Egypt.[d] Al-'Awwām and al-Maqrīzī described essentially the same methods; agriculturalists ploughed the ground extensively with a scratch plough and marked out beds (5 m × 2.5 m), which they irrigated by digging channels down the field on all sides of the bed with spades and hoes. Setts were planted in holes 0.5 m apart on the beds and weeds controlled by hoeing until the cane leaves closed in and covered the ground. Irrigation was performed by flooding the irrigation channels, the sugarcane receiving sub-surface water under the

[a] The date of commencement of the sugar industry in Persia remains a matter of controversy, see Deerr (1), pp. 68–9, Laufer (1), pp. 376–7 and Watson, A. M. (1), p. 160, fn. 12.

[b] Jacobsen (1), pp. 57–60.

[c] Watson, Andrew (1), p. 26.

[d] Deerr (1), pp. 80–1, 88–9. See Sarton (1), vol. 2, pt 1, p. 424 for a biography of Abū Zakarīyā Yahyā ibn Muhammad ibn Ahmad ibn-al'-Awwām al-Ishbīlī and Sarton (1), vol. 3, pt 2, p. 1265 for Abū-l-'Abbās Ahmad ibn 'Alī al-Maqrīzī.

beds. The channels also served as drains to remove the excess water in the wet winter period.[a] The Arabs discovered that sugarcane could be ripened by withholding irrigation water a month or so before harvest. Their understanding of this principle derived from the management of fruit crops such as grapes, with which the ripening effect was apparent to all.[b] Modern research has demonstrated that the sucrose ripening of diverse crops is based on the same physiology.[c] 20th-century sugarcane agronomists, ignorant of the Arab discoveries, have congratulated themselves on discovering the relationship between ripening and withholding irrigation water.[d] This relationship has never been recognised in China as far as we know, but with the low autumn and winter rainfall and consequent shortage of irrigation water during the ripening period, it was probably irrelevant. As the Chinese cultivated sugarcane mostly in areas with over 1,500 mm of precipitation per year, which was adequate for crop growth, irrigation regimes aimed at establishing the crop rather than promoting growth, and irrigation did not extend into the ripening period.

Sugarcane cultivation expanded from Europe into the New World via the Atlantic colonies, Madeira (Portuguese) and the Canary islands (Spanish) in the +15th century. They have a similar climate to the Mediterranean (winter rainfall of about 300–500 mm), and the irrigation technology could be readily transferred to the new locations, though it differed in the subsequent Spanish and Portuguese colonies.

Christopher Columbus introduced sugarcane into the first Spanish New World colony, Española,[e] from the Canaries on his second voyage in +1493.[f] Gonzales de Vellosa manufactured the first sugar with a horse-driven mill (*trapiche*) about +1515; earlier cultivators had made syrup by crushing sugarcane with small hand-driven mills.[g] Don Gonzalo Fernández de Oviedo y Valdés, who reached the New World in +1514, stated in his *Historia General y Natural de las Indias* that de Vellosa obtained his workmen from the Canaries.[h] Undoubtedly, there was extensive technology transfer from the Canaries to Española, as a *cédule royale* of +1519 to the Governors of Tenerife, Las Palmos and Castilla da Oro directed them to send artisans skilled in sugar manufacture to Española.[i]

[a] For a summary of how the Mediterranean climate affected plants, man and beasts, see Braudel (1), pp. 231–46.

[b] Bolens (1), p. 76.

[c] Hawker (1).

[d] Humbert (1), pp. 558–62.

[e] Modern Española (Hispaniola) is divided into two nations, Haiti and the Dominican Republic. Haiti is the former French colony of St. Domingue which Spain ceded to France in +1697. The French never regained effective control of St. Domingue after the great slave rebellion of +1791, and the Republic of Haiti was formerly declared in 1804. The Haitians occupied the Spanish half, Santo Domingo, in 1822, but it achieved independence as the Dominican Republic in 1844, see Watts (1), pp. 253–258, 455.

[f] Sauer (2), pp. 210–11, Ratekin (1), p. 2.

[g] Ratekin (1), p. 4.

[h] See Ortiz (1), for a translation of the whole of the sugar section (chapter 8), of Oviedo's *Historia*, see p. 255. See Penrose (1), p. 293 and Turner (1) for biographical detail on Oviedo.

[i] Wright (1), p. 757, doc. 1.

We do not have a detailed description of the agricultural methods employed, but we do know that the first commodity crops of sugarcane planted after +1515 were irrigated; Oviedo recorded irrigation of the cane fields as one of the routine jobs.[a] A +1547 inventory from an Española plantation, Santiago de la Paz, included a plough, three plough shares, five yokes and all the accessories for working oxen.[b] These facts indicate the implementation of Mediterranean methods at this time, a view which is supported by a passage from the *Flore des Antilles* by F. R. de Tussac, who modestly described himself as 'colon de Saint Domingue.' The methods related by de Tussac for the plantations in the French area of Española during the late +18th century, were pure Mediterranean irrigation technology.[c] We know that growers in Mexico and Peru subsequently adopted Mediterranean methods as extant inventories from both countries documented the use of the plough.[d] The early Spanish methods can be readily distinguished from the Portuguese by the application of the scratch plough, which appeared in inventories in Española, Cuba, Mexico and Peru. Carl Ortwin Sauer has put forward the following suggestion for planting in early Hispaniola:[e]

Cane was grown in much the same maner as the Indian natives had cultivated their *conucos* and as the Negroes cared for their own plantings in Africa. The plough had scarcely a place in the plantation. The earth was dug and piled into ridges and mounds into which the cane cuttings were inserted. Thereafter weeding was done by hand for a few weeks, and thereafter the cane was left to itself until it was ready to cut. Instead of the native planting stick the Africans were accustomed to the use of hoes of iron, heavy and long bladed.

This hypothesis has also been put forward by Watts for Española and early plantings in Barbados.[f] Robert Haskett quoted the view of a peer to explain ploughs in the +1547 inventory of the Española *engino*, Santiago de la Paz:[g]

It has been suggested that ploughs were very often brought over to the New World simply because they were part of traditional European agricultural technology ...

[a] Ortiz (1), p. 256.

[b] Haskett (1), p. 61. A single plough with spare shares would be adequate for land preparation of the 25–30 acres that Haskett (1), p. 58 estimated were under sugarcane on Santiago de la Paz

[c] de Tussac (1). vol. 1, pp. 163–4.

[d] We have excellent data for Mexico from the monumental study of Ward Barrett on the Cortés plantations, the records of which date from soon after the conquest until the 20th century. The inventories included ploughs and the records indicated the practice of irrigation. This would have been necessary as the precipitation is about 1000 mm. Barrett ((1), p. 42) recorded that 'Ruiz de Velasco (1937, p. 217) claimed that Cortés and other hacienda managers installed in Morelos the Arab system of irrigation without important modification.' About +1777 there was a change in type and numbers of ploughs in the inventories (p. 44). I suggest that this probably signalled the advent of light double mould-board ploughs from Spain, which could have been adopted to change the irrigation system to enable watering down the furrows, as finally described by Ruiz de Velasco. We will examine this further below. For Peru see Nicholas Cushner ((1), pp. 66–7) who has studied the Jesuit plantations there from about +1600. The methods were not described in detail, but are plainly derived from Muslim Spain as they included ploughing with a scatch plough and irrigation from channels.

[e] Sauer (2), p. 211; see p. 51 for a general discussion of the *conuco* system.

[f] Watts (1), pp. 114, 153.

[g] Haskett (1), p. 61.

Often the plough was kept moldering in a dark corner while tried and true indigenous methods were used instead.

The first point about these hypotheses is that neither Sauer, Watts nor Haskett supplied any evidence or cited any authorities to support their statements.[a] This contrasted with the evidence for the Mediterranean technology in Española, Mexico and Peru. The second major deficiency in their argument was that planting sugarcane on small mounds was a most inappropriate strategy, as sugarcane lodges readily unless supported; the early English settlers on Barbados discovered the drawbacks to this system, as we shall presently see.[b] The *conuco* mounds were excellent techniques for the expanding, fleshy roots of New World staples such as cassava (*Manihot esculenta* Cranz.) and the sweet potato (*Ipomea batatas* Poir.). All data from the Caribbean and the mainland New World indicated that sugarcane was planted in holes or trenches, not on mounds. The only probable case of a modified *conuco* method, occurred in the first years on Barbados, and ended in disaster proving our point. Our scenario for the Spanish New World, is that the sugarcane cultivation got underway on Española using irrigation, this being the only technique that the advisers from the Canaries knew. It is significant that the cultivators selected the well-watered section of the south coast from Santo Domingo city west to Azua. These techniques were transferred unchanged to Mexico and Peru where irrigation proved essential.

With this background we can take a closer look at the climate of Española. Española is far wetter on the average (500–2,000 mm) than the Mediterranean (c. 500 mm), the Canaries (c. 300 mm), Mexico (c. 1,000 mm) and Peru (c. 50 mm); consequently it was possible to grow rainfed cane on a major portion of Española. Ignorant of this fact, the colonists cultivated sugarcane using irrigation. I hypothesise that by the time plantations expanded from the choice riverbank areas, people realised that rainfed crops were feasible, and that the colonists followed the Mediterranean technique of planting in holes in flat fields, except that they found it unnecessary to put in irrigation trenches. These fields of spaced plants in holes would have superficially resembled spaced *conuco* plantings on mounds. Manuel Moreno Fraginals described the standard method of planting in +18th-century Spanish Cuba as planting in spaced holes made by hoe.[c] I believe that any exponent of *conuco* plantings for commodity sugarcane crops must come forth with some more concrete evidence.[d] Fraginals mentioned an additional late-+18th-century method of planting employed on

[a] Haskett did not cite any written authorities, it was a concept he obtained verbally from Professor David Street of the University of California at Santa Cruz.

[b] A Chinese strategy for keeping sugarcane erect was to tie the leaves of plants in adjacent rows together, see East India Company (1), p. 84.

[c] Fraginals (1), p. 89.

[d] It is feasible that the Indians may have grown odd stools of sugarcane in their *conuco* subsistence gardens, where the cane could have been supported with stakes.

some plantations in Cuba, where the digging stick was forced into the ground at an angle and waggled to make a hole into which seed cane could be inserted, the excess was chopped off with a machete, and the hole closed with a foot.[a] This method is still practised in the Caribbean today.[b] Mediterranean agricultural methods remained paramount in the Spanish colonies until the mid +18th century when there is evidence of new methods from Europe that probably received stimulation from China. This has been called the European agricultural revolution, and we will examine it further in our account of the Chinese experience.

The Portuguese colonies underwent a different technological history. This is of additional importance as they supplied the technology adopted in the English and French colonies in the Caribbean. The Portuguese colonised Madeira in +1420, and it soon achieved prominence as a sugar exporter.[c] The climate resembled that of the Mediterranean with a predominantly winter rainfall of about 500 mm. However, the terrain proved completely different, as the land rises steeply from water's edge to a height of about 2,000 metres in the middle of the island. Colonists conducted agriculture on bench terraces watered by the so-called *levadas*, contour irrigation channels, which diverted water from numerous mountain streams. The scratch plough, which to be effective depended on cross as well as longitudinal ploughing, would have been ineffective on the narrow bench terraces. Ploughing received no mention in Portuguese colonies until the Benedictines introduced mould-board ploughs on their plantations in +18th-century Brazil. Again this was most probably a spin-off of the European agricultural revolution.[d] The Portuguese enlisted experts from Madeira, San Tomé, the Canaries and Europe to establish sugar production in Brazil.[e] We do not know the exact methods they introduced, but as all these areas employed irrigation, it is reasonable to suppose that the first efforts in Brazil included irrigation. Brazil has a favourable climate for rainfed sugarcane, the precipitation varying between 1,300 and 2,300 mm in Pernambuco, the nuclear area for technology adopted in the British and French Caribbean. There must have been a period of considerable adaption in farming methods, during which the Brazilians found by experiment that irrigation was not necessary, and that a 12–14 months plant crop gave better yields than the 9–10 months crop grown in the Mediterranean. Stuart Schwartz remarked that there is little hard data on planting methods in early Brazil,[f] but what is available can be augmented with

[a] Fraginals (1), p. 89. There was even a technological 'advance' in this simple procedure with the introduction of iron digging sticks in the 19th century.

[b] Blume (1), p. 69.

[c] Rau (1) and Greenfield (1).

[d] Schwartz (2), p. 17. The time of introduction of the plough, about +1770, indicated that this mould-board plough (*charrua*) was the new light-weight mould-board, which was gaining popularity in Europe at this time.

[e] Schwartz (1), pp. 16–22.

[f] Schwartz (1), p. 106.

records of the early methods employed in the British and French colonies in the Caribbean, which derived their technology from Brazil.[a] Schwartz demonstrated that there was some planting in holes in Brazil with setts inserted vertically,[b] and I suggest some horizontal planting in rectangular holes as contemporaries recorded it for Guadeloupe.[c] In Barbados holes were dug in rows with three-feet inter-rows, while in Guadeloupe the inter-rows measured two to three feet depending on soil type.[d] Schwartz documented a new method of planting in Brazil, called trenching, that rapidly assumed dominance. It consisted of making trenches the length of the field with hoes, two setts being laid side by side in the trenches. The germinating cane was cultivated by hoe until it closed in, and three weedings were usual practice.[e] Schwartz did not specify any dimensions of the rows and inter-rows, but Andre João Antonil, recorded rows of two spans wide and one and a half deep in his *Cultura e Opulencia do Brasil por Suas Drogas e Minas* of +1711,[f] while in Barbados the inter-rows measured two to three feet.[g] The origin of this trenching system remains obscure, and the early agriculture of Madeira and San Tomé from which it may be derived is equally uncertain. Both areas practised irrigated agriculture,[h] and it is possible the trench system was developed initially for irrigation. As stated earlier, the colonisers of Madeira had to evolve a system of terraces to grow sugarcane. Perhaps a system of trenches where water could be directed down individual furrows, rather than subsurface through special channels, proved more appropriate. Irrigation channels would take up extra land on the narrow terraces and it would be logical to eliminate them. This is merely presented as a hypothesis for further testing.

The Dutch occupied a large area of north-eastern Brazil around Pernambuco from +1630 to +1654.[i] During their occupancy planters from Barbados visited Pernambuco to learn how to grow and mill sugarcane.[j] In his *A True and Exact*

[a] The British colonies obtained their technology from Brazil via Barbados; about +1647, planters visited Pernambuco to gain information, see Ligon (1), p. 85. The French colonies gained some of their information from Dutch refugees after their expulsion from Pernambuco in +1654, see Watts (1), p. 297. Schnakenbourg ((1), pp. 286–9), is sceptical of this common view of the role of the Dutch refugees in bringing Brazilian technology to Martinique and Guadeloupe. He provided evidence that the technology was there before the Dutch arrived, and that they only influenced the technique of claying sugar, which the Portuguese had previously used, but not understood properly.

[b] Schwartz (1), p. 107.

[c] Labat (1), vol. 1, p. 233.

[d] For Barbados, Stearns (1), p. 178; for Guadeloupe, Labat (1), vol. 1, p. 233.

[e] Schwartz (1), pp. 107–8.

[f] Antonil (1), p. 152.

[g] Ligon (1), p. 85, Stearns (1), p. 178.

[h] We have noted Madeira above. Marian Malowist ((1), p. 15) wrote that sugar mills on San Tomé were located alongside water courses to enable utilisation of hydraulic power for driving the mill machinery, and irrigating the fields.

[i] Schwartz (1), p. 108. After their expulsion a number immigrated to Guadeloupe via Martinique and were welcomed for their experience in sugarcane manufacture, see Deerr (1), p. 231, Watts (1), p. 297.

[j] Ligon (1), p. 85.

History of the Island of Barbados of +1657, Richard Ligon related how the English commenced sugar production with no knowledge of the crop; they had no prior experience in growing sugarcane and no experts to appeal to for advice. They apparently first employed a modified form of the Arawak Indian *conuco* system of planting on spaced mounds. The English found Barbados uninhabited on their arrival in +1627, so their leader John Powell recruited thirty-two Arawak Indians from the Essequibo district on the South American mainland, who brought seeds and animals, and exposed the colonists to tropical agriculture.[a] When the colonists turned to sugarcane in the mid +1640s they followed indigenous methods. Ligon wrote.[b] 'their maner was to dig small holes, at three foot distance, or thereabout, and put in the plants endwise, with little stooping'. 'With little stooping' bears the connotation of poking the setts into mounds, or perhaps just into a loosened surface hole. Disastrous results ensued with the sugarcane lodging, and weeds and vines smothering it. This resulted in rotten cane 'unfit for service in making good sugar.[c] Ligon confessed that an ordeal of considerable trial and error followed, and several trips to Pernambuco were necessary to obtain information.[d] After the initial disasters, they resolved to try the trenching method discussed above, a Brazilian technique, which proved highly successful at first.[e]

In the mid +17th century Henry Oldenburg, Secretary of the Royal Society, solicited 'Inquiries' from informed people in distant lands on trades and practices so that discussion might produce 'mutual benefits to trade and experimental philosophy'. Raymond Phinaeus Stearns has found an 'Inquiry' on the sugar industry of Barbados c. +1667 in the archives of the Royal Society. Stearns suggested Edward Littleton as the author of the anonymous document. Littleton, later a prominent planter who championed the cause of his class in England, most probably obtained his information from a leading planter James Drax (Drake).[f] The methods documented included the following:[g]

> The way of planting is either by *Holes*, made at 2 foot distance in the rank and 3 in the file, or by Trenches, laying the Canes all along, one close to the end of the other; whereupon from every Joint of the Cane, thus laid, will sprout out new Canes.

'Holes' is italicised in the text, indicating some sort of modified hole present some seventeen years after Ligon left Barbados in +1650. A holing method that survived alongside trenching must have been different to the original '*conuco*' method that proved disastrous. For a full account of the new Barbadian

[a] Watts (1), pp. 152–3.
[b] Ligon (1), p. 87.
[c] *Ibid.*
[d] Ligon (1), p. 85.
[e] *Ibid.* p. 87.
[f] Littleton is famous for a tract *The Groans from the Plantation* (London, +1689). The reader may be excused for thinking that it concerned slavery, but in reality the 'groans' were from the plantation owners complaining about duties imposed on Barbadian sugar.
[g] Stearns (1), p. 178.



Fig. 38. Large hole planting on the island of Antigua in the +18th century. The hole system depicted was developed on the island of Barbados about +1700. Slaves first marked the field out in squares of 3.5 to 5 feet, and dug holes of 2 to 3 feet square and 0.5 inches deep in the centre of the square. They shaped the hole to about 1.25 feet square at the bottom, and threw the soil dug from the holes on the downhill side to form banks across the slope. The shaped hole allowed any precipitation to flow to the cane planted at the bottom of the hole; detail from a plate in W. Clark, *Ten Views of Antigua*, 1823; through Deerr (1), vol. 1, pl. 13, opposite p. 174.

holes, that spread elsewhere in the Caribbean, we have to await Bryan Edwards, and his *The History, Civil and Commercial, of the British Colonies in the West Indies* of +1793:[a]

Each plat is then sub-divided, by means of a line and wooden pegs, into small squares of about three feet and a half. Sometimes indeed the squares are a foot larger; but this circumstance makes but little difference. The negroes are then placed in a row on the first line, one to a square, and directed to dig out with their hoes the several squares, commonly to a depth of five or six inches. The mold which is dug up being formed into a bank at the lower side, the excavation or cane-hole seldom exceeds fifteen inches in width at the bottom, and two feet and one half at the top. The negroes then fall back to the next line and proceed as before.

Seen in conjunction with William Clark's painting of holing in Antigua (Fig. 38), this passage clearly indicated how slaves constructed cane holes in the +18th-century Caribbean. The dimension of holes, and space between holes varied with locality. The space between holes ranged from about 0.15 m in Antigua to 1.0 m in Barbados. The Barbadian and Antiguan holes were also more box-like than the shaped Jamaican hole.

[a] Edwards (1), vol. 2, p. 215.

The origin of the holing technique remains obscure, but I suggest that the Barbadian cane hole was a further development of the original Mediterranean system that arrived in Barbados via Brazil. The technique probably arose sometime before +1670 when Littleton documented *holes* in his manuscript.[a] The Barbadian system only differed from the original holes in the Mediterranean, subsurface irrigated beds, in the shaping and size of the hole, and the distance between holes. I hypothesise that the holes were fashioned to direct scarce water onto plants, and the distance widened between holes so that other crops could be grown on the inter-rows. David Watts suggested that the cane hole system was primarily devised in Barbados to replace the trenching system as an erosion control measure. I very much doubt this, as trenches across the slope, two feet apart and heavily planted, provide an excellent method of erosion control as they prevented water from flowing down the slope. Of course, maximum protection occurred when the rows lay on the contours of the slope. Watts reported cases of planting with the rows down the slope, a practice which undoubtedly caused extensive erosion; this erosion resulted from bad management, not bad technique. I further suggest that erosion caused by inappropriate trenching probably triggered the development of the Barbadian hole system, which aimed to rejuvenate the affected land. The Chinese were probably the first to adapt intensive hole-type agriculture to grow crops on eroded, marginal land. They grew millet, wheat, taro, soya beans in holes during the −1st century under a procedure known as 'pit cultivation' (*ou thien*[1]).[b] Technologists also employed intensive holing with sugarcane to good effect on marginal land in modern India.[c] Hole-and-pit cultivation aimed to raise agriculture to the level of horticulture with a vastly improved micro-environment for individual stools. Fertiliser was not wasted on inter-rows, since it was applied directly to the plants, which were cultivated individually. Just as important, the shape of the pit directed all moisture that falls in odd showers in dry periods onto the plant. This was most vital as most cane-growing areas in the Caribbean lay close to the critical precipitation of 1,200 mm per year.[d]

Since other crops, such as aroids, yams, corn or peas were interplanted with sugarcane in the new hole system,[e] I suggest along with Watts,[f] that an additional reason for holing was the need to ease land pressure in an intensified

[a] Watts ((1), p. 402) said the Barbadian holing system appeared in the early +18 century. His first evidence of holing, in a document of +1707, was quoted as 'Mr. Arnol . . . did send thirty negroes for two dayes to help hole a piece of ground.' This was no better evidence than Litteton's document of c. +1667. Neither document gave a description of the actual nature of the holes.

[b] Vol. 6, pt 2, p. 127 and Shih Sheng-han (2), pp. 31–41.

[c] Singh, Yadav, Hora, Singh, Singh & Singh (1).

[d] For example, Antigua, 1,000 mm, Barbados 1,200–1,900 mm, St. Kitts 1,350 mm.

[e] Watts (1), p. 404.

[f] *Ibid.*

[1] 番 田

farming system. In the trench method planters made the rows so close that it would be difficult to intercrop, and in addition so close that cane yields and quality must have decreased.[a] I will present a similar argument to explain the widening of sugarcane rows north of the ranges in China during the early +17th century.

The scratch plough was not utilised in the systems that emerged in Brazil, and in the later English and French colonies in the Caribbean. The hoe and digging stick were universally utilised until the mould-board plough, introduced in the mid +18th century, slowly gained ground over the next 100 years on appropriate soils. The reluctance to adopt the plough has been attributed to slavery; labour-saving technology not being necessary when slaves were available. Through the +17th and +18th centuries this argument was directed at Caribbean plantation owners, and they countered with ideas that hoes and planting in holes were necessary to conserve moisture and handle heavy soils.[b] The holing system, with associated trash mulching, continued in Barbados after emancipation until the 1960s, when escalating costs finally forced a changeover to the plough. This had disastrous affects on yields, and holing/mulching had to be re-introduced.[c] It is evident that the cane hole-and-mulching system proved essential for the thin, calcarious soils with precipitation of about 1,500 mm or less in the Caribbean. With higher precipitation in Brazil, the problem was the heavy nature of the soils, which planters overcame by adopting light mould-board ploughs when they became available about +1770. From the 19th century onwards, the mould-board plough gained increasing popularity in districts with over 1,500 mm precipitation in all countries, and the methods exhibited surprisingly Chinese features.

(iii) Summary of world methods and initial contrast with Chinese sugarcane agriculture

The indigenous methods of South-East Asia, Indonesia and Oceania of seed-bed cultivation with digging sticks and space planting in holes or on mounds at centres of 1–2 m, was basic, but effective, for a subsistence level of production. The methods evolved in India proved capable of higher levels of production due to the introduction of the scratch plough for seed-bed preparation, but broadcast methods of planting did not allow efficient cultivation and irrigation. Irregular spacing of plants must have led to competition and decreased cane yields and sugar content. The Muslim agronomists employed more refined methods, and planted sugarcane in rows on raised beds with good drainage

[a] See review in Humbert (1), pp. 112–15. Virtually all experiments in the tropics show greater tonnage and sucrose with inter-rows in the range 4.5 to 5.5 ft.

[b] The literature on sugar and slavery is voluminous, see in particular Aufhauser (1), Knight, Franklin W. (1); for the problems of the plough in Brazil, see Schwartz (1), p. 107.

[c] Hudson (1).

and irrigation. They prepared fields with ploughs, but subsequent cultivation involved highly labour-intensive methods, and their subsurface irrigation techniques wasted water. The systems that evolved in the New World show a retrogression in technique rather than an advance, but aimed to adapt sugarcane cultivation to thin, drought-prone Caribbean soils that could not be irrigated. In most areas, ploughing and animal-driven cultivation was completely eliminated, but volume production increased with a massive injection of slave labour.

In contrast, in China by the late +16th century, sugarcane agriculture in Fukien and areas north of the ranges, had reached a level where all the major principles of animal-powered cultivation had been developed. After the +17th century Chinese immigrants practised these methods overseas in the Indonesian Archipelago and other parts of South-East Asia. The methods appeared so effective that European emancipationists claimed that free men in Java and Sumatra could make sugar at lower costs than their West Indian counterparts.[a] In the following pages we describe Chinese sugarcane agriculture and the historical development of the new technology.

(4) Sugarcane Agriculture in China North and South of the Ranges

Sugarcane agriculture can be best understood by treating operations in the natural order of the crop cycle:

(i) selection of land for sugarcane
(ii) selection of clones and provision of seed cane
(iii) land preparation, drainage and planting
(iv) weed control and inter-row cultivation
(v) irrigation
(vi) fertilisation
(vii) growth and harvesting
(viii) ratooning
(ix) crop rotation
(x) intercropping
(xi) pests, diseases and acts of God

Where necessary we will discuss these operations under the sub-headings, north and south of the ranges.

Before commencing we must note that reconstructing the history of agricultural operations in space and time presents very grave problems. These have been dissected by G. E. Mingay in a perceptive introduction to a selection of

[a] See evidence presented by Botham in East India Company (1). Of course, these Chinese 'free men' were not truly free as many of them were bonded to merchants.

source materials on the English Agricultural Revolution, of +1650 to +1880.[a] This includes several observations very relevant for our study:[b]

1 'the chance survival of records and the problems of their interpretation often make it difficult to date with precision or certainty the earliest introduction of a new practice'
2 'there is also the matter of distinguishing between haphazard experimentation and systematic development of an innovation'
3 'to give any very clear idea of when an innovation became a significant influence on production is also problematical'
4 'it will be generally accepted that the period of widespread adoption ... is more significant than the earliest known date of its introduction'
5 'the problem of dating widespread adoption arises because many innovations only had a limited sphere of application'.

This provides some exceptionally useful guidelines, and it will become evident that these problems have to be faced in tracing the history of Chinese sugarcane agriculture and manufacture. There are hardly a handful of detailed original sources for examining the technological development of Chinese sugarcane agriculture. Fortunately for the later periods we can use evidence from the technology transferred overseas to throw light on techniques employed in the homeland. We often recognise traditional Chinese implements, such as the traction spade in Java, that are not mentioned in any indigenous Chinese sugarcane texts. Similarly, Henry Botham's description of inter-row cultivation with mould-board ploughs in Sumatra makes it easier to interpret the briefer more telegraphic text of the *Thien Kung Khai Wu* of +1637. Nevertheless, in most cases it remains difficult to date how widespread an innovation was, and how rapidly it diffused.

(i) *Selection of land for sugarcane*

Though there are no sources prior to the Han dynasty, we may assume that before that period, the Yüeh cultivated sugarcane on the delta areas of south China along with rice, and on hillsides under a slash-and-burn system in polycultural (mixed) gardens.[c] Although sugarcane was probably grown as a monoculture from about +400, it is not until the Ming dynasty that agricultural treatises began to record the selection of sugarcane-growing land. The first au-

[a] Mingay ((1), pp. 1–4) pointed out that the English Agricultural Revolution can hardly be termed a revolution as it extended for over 200 years, and possibly included four mini-revolutions detected by other scholars. The story of this 'revolution' provides firm evidence of the conservatism of European farming and makes odious the pretensions of the +19th-century English agriculturalists in India who considered 'the Indian cultivator and artisan incapable of improvement'. This was quoted by Sir George Watt ((1) vol. 1, pt 2, p. 257), as typical English comment, prior to demolishing the statement on other grounds himself.

[b] Mingay (1), pp. 4–5.

[c] See argument in Bellwood (2), pp. 111–16.

thor to broach this subject was Sung Ying-Hsing[1], who in his *Thien Kung Khai Wu*[2] of +1637 recommended planting on alluvial soil beside rivers:[a]

Sugarcane must be grown on sandy soil, the best being the alluvial soil beside rivers. To test the nature of the soil dig a hole about 1.5 *chhih*[3] [deep] and taste the sandy soil with the mouth. Soil with a bitter taste is unsuitable for planting sugarcane. However, [sugarcane] should not be planted on alluvial soil along the upper reaches of rivers close to deep mountains, even if it tastes sweet, because the cold nature of mountain air later will make the flavour of the sugar bitter. Select good flat alluvial soil that is exposed to sunlight forty to fifty *li*[4] from the mountains for planting [sugarcane]. (Yellow clay bottom soil should never be used.)

This text obviously included local folklore, but offered sound advice in directing attention to the well-drained alluvial soils in minimal frost areas. Sung Ying-Hsing specifically warned against planting on alluvial land at the upper reaches of rivers because of 'the cold nature of mountain air' which brought frost damage to the cane, and restricted the length of the growing season. Later sources also recorded that sugarcane in Fukien and Kuang-Tung was grown on sandy soil beside rivers,[b] but later generations definitely did not observe the injunction in the *Thien Kung Khai Wu* against planting near mountains because of susceptibility to cold damage; agriculturalists grew it on hilly land or undeveloped land, in both the northern and southern zones.[c] (see Fig. 39) In the southern zone this included large areas of flat marshy land drained or reclaimed on the Pearl River delta.[d] Sandy alluvial soils and hillside land are both appropriate for sugarcane as they come under moisture stress after the monsoon boom growth period, and this aids ripening. Sugarcane ripens slowly on reclaimed marshy land, but it achieves high levels of sugar per acre because of the massive physical yield of cane.

We will now examine the factors that forced sugarcane onto land considered inappropriate by the *Thien Kung Khai Wu*. The *Min Shu* of +1631 recorded that in Chhüan-Chou prefecture, one of the Fukienese centres of sugar production after the +15th century, 'people living near the mountains opened up hard and

[a] *TKKW*, p. 163.

[b] *Chih Wu Ming Shih Thu Khao*, ch. 32, p. 27b. The *THSCL* of +1736, p. 56 recorded relatively flat sandy soil as suitable for sugarcane cultivation in south Taiwan. Observations by the Macartney mission in the late +18th century indicated that in Chiang-Hsi much sugarcane was grown 'on a sandy soil above the river', and that it was extensively irrigated by noria wheels and chain-pumps, see Staunton (1), vol. 3, p. 335. Some sources, such as the Ssu-Chhuanese work *San Nung Chi* ch. 17, p. 7a, recorded that sugarcane is suitable for planting on sandy soil.

[c] In Ssu-Chhuan peasants grew sugarcane on both hill land (*shan thu*[5]) and flat land (*pa thu*[6]), the former reportedly giving the highest yields, see Kanda (1), pp. 522–3. Eckeberg recorded sugarcane planted on two different types of land: in 'low places' (presumably irrigated alluvial soil) and on 'hills'. He also noted that the planting schedule differed, planting in the 'low places' took place in March and April, while on the 'hills' it was done in the rainy season, probably around June, July or August, see Osbeck (1), p. 296.

[d] Mazumdar (1), pp. 241–4.

[1] 宋應星 [2] 天工開物 [3] 尺 [4] 里 [5] 山土
[6] 埧土



Fig. 39. Sugarcane on terraced hillsides and valley floors at Hua-Nien[1], Yunnan, January 1990. The terraces are irrigated from tanks on top of the mountain. On the valley floors sugarcane competes with paddy rice, the fields of which are just beginning to be prepared; orig. photo Christian Daniels.

barren land to grow sugarcane and boil sugar' to market all over the Empire.[a] Market forces constituted a major factor in the expansion. The domestic Chinese sugar market began to expand, along with the infiltration of the money economy into south-eastern regions, from the +16th century. There is little doubt that the development of the coastal trade between north and south China after the mid-Ming, triggered this expansion.[b] In some key sugar districts sugarcane even invaded land normally reserved for paddy rice,[c] a practice which galled local officials during the Ming and Chhing periods, and occasionally prompted them to prohibit its cultivation, because they feared outbreaks of food shortages arising from falls in local grain production.[d] In Hsing-

[a] *MS*, ch. 38, pp. 2a–2b.

[b] Matsuura Akira (*1*).

[c] Such as Kuang-Chou, Fu-Chou and Hsing-Hua.

[d] For example the late Ming author Chhên Mao-Jen[2] in his description of the Chhüan-Chou[3] region wrote; 'People frequently change to growing sugarcane in rice fields and rice is consequently becoming increasingly scarce. All is dependent on supplies from Chekiang and Chih-Li which are shipped by sea for sale [here]', see *Chhüan Nan Tsa Chih*, p. 3b. For a prohibition against growing sugarcane on rice land issued in Taiwan during the early +1690s, see the +1696 *Thai-Wan FC*, pp. 250–1.

[1] 化念 [2] 陳懋仁 [3] 泉州

Hua prefecture this process had already started during the late +15th century.[a] It progressed more slowly in Kuang-Chou prefecture where the area of land under sugarcane reportedly equalled the area under rice, in three of the sixteen counties during the late +17th century.[b] I also suggest that markets may have expanded for areas south of the ranges with the climatic cold taking effect from the +16th century. I have mentioned previously the possibility of cold as a major factor in the demise of sugar production on the Min river, Fukien, in general terms (see p. 186). More specifically, the alluvial land on the famous Sugarcane Sandbar (*Kan-Chê Chou*[1]) in Fu-Chou[2] prefecture, supported several hundred households, all of whom engaged in cane growing for their livelihood during the late +15th century.[c] Thereafter it seems to have disappeared from the historical record as a sugarcane district, possibly, in part, in response to the change in temperature. The growing market for sugar in an expanding cash economy acted as a major force in opening up land.

Apart from the market mechanism, the expansion of cane growing to 'hard and barren land' in Chhüan-Chou also arose from population pressure on existing developed land. This was not restricted to Chhüan-Chou, and increasing population pressure constituted another major factor in the general extension onto marginal land. In Tung-Kuan county in the Pearl River delta during the +1680s, for example, agriculturalists grew sugarcane on 'hard alkaline soil unsuitable for the cultivation [of other crops]' that was sandwiched between a river and steep mountains behind.[d] Another gazetteer of the +1680s for Po-Lo county[3] in Hui-Chou prefecture[4], Kuang-Tung, related that 'sugarcane is produced in the waste areas where Fukienese people clear the wilderness (*tshao lai*[5]) to plant it'.[e] In addition, the reclamation of low-lying and marshy land became intensified in the Pearl River delta after the +17th century. Land had been poldered in this area from the Sung dynasty in a leisurely fashion. The process consisted of laying a low wall of stones around the selected area to trap sand and silt during ebb-tide. When a sufficient volume of 'soil' had accumulated, salt-tolerant reeds and aqueous plants were planted to further the reclamation. After an adequate deposit had built up, a dyke was constructed to keep out the sea, the land drained, and crops planted after sufficient leaching of the salt by rainwater; this process could take up to ten years.[f] Concurrently with the +17th-century polder expansion, land was converted into the well-known dyke-pond system. Mulberry trees were grown on the dykes for silk production, while fish were raised in the ponds, the silk worm excrement being

[a] +1503 *Hsing-Hua FC*, ch. 12, p. 11b and ch. 13, p. 10b; Tai (1), p. 51; Rawski (1), pp. 48–9.
[b] *KTHY*, p. 689.
[c] *Pa Min Thung Chih*, ch. 4, p. 13b. This is probably the centre of sugar production mentioned by Marco Polo, which later declined.
[d] +1689 *Tung-Kuan HC*, ch. 2/4, p. 3a.
[e] +1687 *Po-Lo HC*, ch. 1, p. 69a.
[f] Mazumdar (1), p. 244.

[1] 甘蔗洲 [2] 福州 [3] 博羅縣 [4] 惠州府 [5] 草寮

used to feed the fish, and fertilise the mulberry trees and other minor crops on the dyke land (*chi ti*[1]) in a self-sustaining regime.[a] Sugarcane probably had been a minor crop, along with the lichee[2] (*Litchi sinensis*) and longan[3] (*Euphoria longana*), from the establishment of the dykes in the +14th century, and continued to be cultivated during the mulberry-silk worm period. During the great world depression in the 1920s the silk industry failed and sugar manufacture replaced it as a major activity. Sugarcane now constitutes the major crop in the dyke-pond system.[b]

We see the combined effects of population pressure and market opportunities in south Taiwan from the +17th century onwards. Sugarcane cultivation commenced on newly opened land with no facilities for irrigation; less labour was required for developing the land for cane growing than for rice paddy cultivation.[c] Production prospered because of a great demand for sugar for export to Japan, Java, Persia, as well as the domestic Chinese market after the +1690s.[d] Sugarcane cultivation undoubtedly constituted the medium through which much of the virgin land in south China and south Taiwan was opened up. Sugarcane was an excellent crop for developing new lands, as the wood from the felled trees could fuel the boilers for sugar making. In many sugar regions of the world, such as the Mediterranean during the middle ages and the Caribbean during the +17th and +18th centuries, deforestation and the resulting shortage of wood fuel, were major factors affecting the prosperity of production.[e] I conclude that the growing market for sugar within the Chinese Empire and overseas in the case of Taiwan, together with the availability of associated timber for fuel, acted as major factors promoting the cultivation of sugarcane.

(ii) *Selection of clones and provision of seed cane*

Areas north and south of the ranges exhibited great differences in regard to this subject.

[a] See Ruddle and Zhong (1), pp. 74–7, 99–100, a monograph, for the most comprehensive treatment of the dyke-pond system and the incorporation of sugarcane into the regime. There is additional worthwhile material in Chhing Kung-Yeh-Pu ... (*1*), pp. 254–5, Faure (1), pp. 15–17 and Blume (1), pp. 242–3.

[b] See Ruddle and Zhong (1), pp. 14–28 for the history of the system, pp. 74–7 for the extent and management of sugarcane and pp. 99–100 for labour in-put and the cultivation system for sugarcane.

[c] This was successful because of a rainfall of about 1,800 mm.

[d] The Dutch East India Company initiated the commodity production of sugar by bringing Chinese peasants to Taiwan to grow sugarcane and make sugar from the +1620s. The Dutch, who organised and controlled the industry, only provided the capital for production and exported the sugar to Japan, Java, and Persia. Chêng Chhêng Kung or Koxinga, as he is known in Western sources, encouraged sugar production after ousting the Dutch from Taiwan in +1661 and probably used the profits gained from sugar exports to finance his campaigns against the Chhing. Direct exports of sugar from Taiwan to Japan continued until the +18th century after which they were probably exported via Amoy or other ports in Fukien. For sugar exports see Iwao (*1*), p. 126; Iwao (*2*), and for the Chinese domestic market see Daniels (*2*).

[e] Lombard (1); Galloway (1), pp. 187–8; Galloway (3), pp. 336, 340, and 342.

[1] 基地 [2] 荔枝 [3] 龍眼

North of the ranges

Clones planted in the north had to be more tolerant to cold and harsh conditions than those south of the ranges. We have seen that this resulted in miscanthus cane *ti-chê*[1], attaining dominance in the north, with bamboo cane *chu chê*[2] (both *S. sinense* clones) planted on the richer land, and under more sheltered situations. *Khun-lun chê*[3] (*S. officinarum*), cultivated for chewing, appeared along with the other two clones depending on the severity of climate and personal taste.

In most areas north of the ranges sugarcane had to be harvested before the onset of winter to avoid damage from frost, thereby leaving no seed cane for spring planting. If special seed beds were left unharvested, frost killed the eyes of the cane which rendered them useless as planting material. There are four ways of overcoming this problem of storing seed cane over the winter for spring planting. First, the sugarcane can be planted in autumn ahead of the frost with a cover of up to six inches of soil. The cane germinates or remains dormant, the cold killing any above-ground portion during the winter. In the spring of the following year any dead shoots above ground are chopped down, some soil removed from the rows and the sugarcane cultivated as normal. As far as we know this method had not been reported for China.[a] Second, in the spring the root stock of a ratooned crop can be dug up, and chopped into convenient pieces and these pieces planted in holes or furrows. This method may have been used to a minor extent as it is mentioned by Osbeck, but south of the ranges.[b] Third, prior to frosting the seed cane can be cut, placed in piles and the piles covered with a thick layer of earth, and dug up during the spring.[c] Fourth, the seed cane can be cut prior to frosting and stored in pits with stalks placed either vertically or horizontally. The pits are then sealed from the air and left until the spring when they are opened. In some areas, where agriculturalists had to preserve large amounts of seed cane, they stored the cane in trenches, which can be considered as large pits. Only the fourth method has been detected in pre-modern northern China, and it is still the most important way of solving the storage problem today (see Fig. 40).[d]

The first clear account of the storage of seed cane in subterranean pits appeared in the *Thang Shuang Phu*[4] of c. +1154:[e]

[a] This method is widely used in Louisiana and Argentina, see Blackburn (1), pp. 150–1.

[b] Osbeck (1), p. 296. Root stocks are likely to be available in areas where sugarcane is rotated with crops that have to be planted after the sugarcane is harvested. Planting from root stocks was employed extensively in Muslim Spain, see Ibn al-Awwām through Deerr (1), p. 80.

[c] This is a most obvious method and may have been used in ancient India as it survived into the 19th century, see Watt (1), vol. 6, pt 2, p. 188. This method was widely employed in 19th-century Louisiana where the practice was called 'windrowing', Blackburn (1), p. 150.

[d] For details of storage methods in modern China see Chhing Kung Yeh Pu . . . (1), pp. 299–302.

[e] *TSP*, p. 3a; Liu & Liu (1), p. 14.

[1] 荻蔗 [2] 竹蔗 [3] 崑崙蔗 [4] 糖霜譜

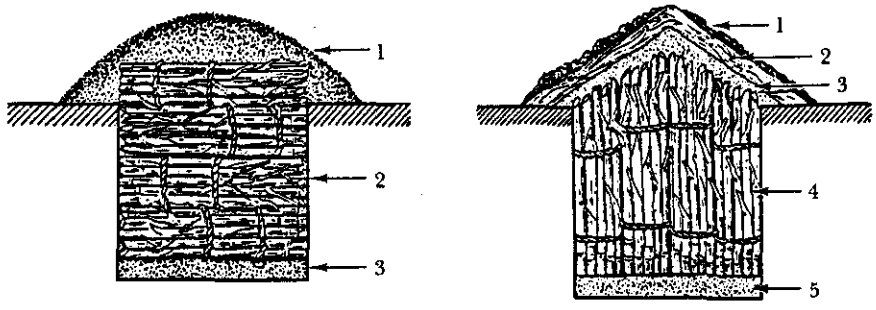


Fig. 40. Pits for storing seed cane in 20th-century China as illustrated in Chhing Kung Yeh Pu ... (*1*), pp. 300–1. Horizontal storage is depicted in Fig. 40*a*, where (1) indicates a hard clay top, (2) seed cane including trash and (3) soft fine clay lining. Vertical storage is depicted in Fig. 40*b*, where (1) indicates a hard clay top, (2) leaves of sugarcane, (3) fine clay lining, (4) seed cane including trash and (5) soft fine clay lining. These storage pits are designed to keep the seed cane in an airtight, waterproof environment. The stalks are stored over winter and dug up in spring for planting.

Select short stalked canes (buds grow on the internodes, and if [internodes] are shorter the nodes will be closer together and the buds greater in number). Dig a pit two *chhih*[1] [62 cm] deep making it as wide as is convenient. Cut off the tops [of the cane], stand them upside down in the pit and [cover] them over with soil (if the cane is not inverted, rainwater will enter the leaf axles which must after a while rot [the buds]).

Cultivators dug subterranean pits deep enough for cane stalks to be stood up on their ends. Pits are an ancient Chinese strategy, dating from −5000, designed to preserve grain seed for planting in the next spring and for food.[a] We can safely assume that the need to store seed cane in subterranean pits arose with the commencement of the commodity production of sugarcane in the northern zone. This is an excellent example of technology transfer from one crop to another.

It is not surprising that the first description of subterranean pit storage in connection with sugarcane came from Ssu-Chhuan, as the cold weather there made it essential to protect seed cane from frost damage. These facilities aimed to keep the pit air-tight so that the carbon dioxide produced from the respiration of the crop stored killed any pathogens inside. The Yüan dynasty text, the *Nung Sang Chi Yao*[2], described the storage of seed cane:[b]

Dig a deep pit, line the pit bottom with straw and store the stalks of sugarcane by standing them up vertically. Place wooden boards over the top and cover with soil to prevent air getting in and frost damage. In the spring of the following year, remove the seed

[a] See Vol. 6, pt 2, pp. 394–402.
[b] *NSCY*, ch. 6, p. 14a.

[1] 尺 [2] 農桑輯要

cane from the pit at an appropriate time, cut [it into setts] and plant it as described above.

The purpose of placing a wooden board on top of the pit was to keep it air-tight.[a] Though some subterranean pits for grain storage seem to have been waterproofed,[b] the *Thang Shuang Phu* passage cited above showed that this was not always the case. This text warned that rainwater will seep into the leaf axles and rot the buds, if the cane stalks were not inverted. Perhaps it proved too difficult to completely waterproof pits in Sui-Ning in Ssu-Chhuan where the weather was wetter than the drier climate of north China.[c] Today peasants line the pits with soft fine clay[d] to prevent water seeping in (see Fig. 40). Also it may not have been necessary to go to the trouble of waterproofing pits if the problem could be solved simply by standing the stalks upside down as recorded in the *Nung Sang Chi Yao*.

The *San Nung Chi*[1] by the +18th-century Ssu-Chhuanese writer Chang Tsung-Fa[2], provided a most detailed passage on pit storage:[e]

> At the time when the frost is about to fall, take advantage of the clear and fine weather to cut the [sugarcane] together with all the roots. Remove the leaves and tops of the cane and retain the stalk, and store it inside a subterranean pit. The pit should be dug like a drain; narrow in width, straight and long. It should be five or six *chhih*[3] [approx. 1.6–1.9 m] in depth. Line the bottom with straw and brushwood and store the cane stalks accordingly. Place straw and reeds over the top [of the pit] before covering it with soil. Do not allow the wind to blow through or let water seep in, otherwise the [stalks] may become infected with red rot disease (*hsin hung fu hsiu*[4]). If it is overheated (*cho chiu-chhi*[5] [lit. catches wine air]) then it will be spoiled.

The pit in this case was a long, narrow, deep trench into which stalks of sugarcane must have been inserted horizontally. This passage shows that Chinese agriculturalists knew of the damage that could be rendered by inadequately constructed pits; they realised that air and water could cause red rot disease, and temperatures too high in the pit could spoil the cane. Today Chinese cane growers call the 'overheating' *shao chiao*[6] or 'burning the pit', and manuals warn against the dangers of it.[f] The shape and size of the pits varied, but the evidence consistently demonstrated that the main aim was to prevent air, frost

[a] Tai Kuo-Hui (Tai (*1*), p. 67) commented that the wooden boards were to prevent rainwater from seeping in and rotting the buds, but the *TSP* did not mention lining the bottom and sides of the pit with clay to keep water out. As argued below, it seems that the pits for storing seed cane were not waterproofed, so rather than being solely designed to keep moisture out, a function it obviously did serve, its main purpose was to maintain air-tightness.

[b] Vol. 6, pt 2, pp. 394–402.

[c] In fact the *TKKW*, p. 163 clearly stated that when digging subterranean pits 'avoid low-lying and damp places where water collects'.

[d] Chhing Kung Yeh Pu ... (*1*), pp. 300–1.

[e] *San Nung Chi*, ch. 17, p. 7b.

[f] See Chhing Kung Yeh Pu ... (*1*), p. 299.

[1] 三農紀 [2] 張宗法 [3] 尺 [4] 心紅腐朽 [5] 着酒氣
[6] 燒窖

and water from entering, and to maintain an optimum temperature to prevent pathogens from infecting the seed cane.

During the +17th and +18th centuries agriculturalists in some sugarcane-growing districts did not remove the tops and leaves from the cane stalks for storing in pits, as evidenced by the following passage in the *Chih Fu Chhüan Shu*[1] (The Complete Way to Wealth) of +1620:[a] 'At the beginning of the tenth lunar month collect cane stalks with closely spaced internodes and place them in subterranean pits with the tops and leaves left on.' The same line occurred with slightly different wording in the *Chih Fu Chhüan Shu*[2] of +1678.[b]

In China today, sugarcane stalks are either stood vertically, or laid horizontally in the pits. It is significant that the *Thang Shuang Phu* recommended that cane stalks be stood up vertically on the pit floor. This was the first mention of vertical standing, and the *Nung Sang Chi Yao* recorded the same practice. The first literary reference to the practice of horizontal storage occurred in Ssu-Chhuan in the *San Nung Chi* passage cited above. This suggests that historically speaking vertical laying may have preceded horizontal laying.

Pit storage diffused to Japan, where Ota described it in the 19th century; the stalks were stored horizontally in layers of sand.[c] Joseph-Antoine Valcarcel, the eminent Spanish agronomist, in his *Agricultura General* (+1765 to +1786) documented a method of storing sugarcane tightly packed vertically in three foot deep pits and sealed with a layer of soil, with the leaves left on, as recorded in the *Chih Fu Chhuan Shu.*[d] This method appeared in the *Kitab al-filāha* (Compendium of Agriculture) of +1180 by Ibn al-'Awwām, the medieval Spanish agronomist: 'these (seed) canes freshly cut, or soon after, are placed completely in the earth, leaving them there until the beginning of March.'[e] Below, in 'Conclusions on Agriculture' I discuss the possibilities for diffusion of techniques from China to the Mediterranean and Spain.

Seed cane management and transplanting north of the ranges

By the time of the *Thien Kung Khai Wu* of +1637 we discern a new development in management of seed cane from cane stored in pits:[f]

[a] +1620 *Chih Fu Chhuan Shu*, ch. 5, *chê*.

[b] +1678 *Chih Fu Chhuan Shu*, ch. 1, pp. 25b–26a.

[c] Ota (1), p. 464. Tamura Genyū[2] (+1718 to +1776), who studied Chinese sugarcane agriculture and sugar-making technology in the mid +18th century illustrated a shed with sugarcane stalks laid out horizontally and covered with mats in a manuscript entitled *Kansha Zōsei Den*[3] of +1760. It is not known whether these sheds became widely used.

[d] See the translation from Joseph-Antoine Valcarcel by Thomas Spaulding in Coulter (1), pp. 253–8, the source is not noted but it is presumably from Valcarcel's *Agricultura General* of +1765 to +1786.

[e] See translation in Deerr (1), p. 80.

[f] *TKKW*, p. 163. It is interesting to note that Captain Charles Gustavus Eckeberg, who visited Canton three times during the 1740s, left the following account of planting sugarcane: 'The roots of the sugarcane cut into pieces, (each of which had a shoot or two) were planted more than half a foot deep into the ground; and two feet space was left between every two rows', cited in Osbeck (1), vol. 1, p. 296. In this case germinated root stocks were used as transplants. This may be just an isolated incidence with no wider significance.

[1] 致富全書 [2] 田村元雄 [3] 甘蔗造製傳

Five or six days prior to the *yü shui*[1] [about 19th February] when the weather is clear and fine, remove [the stalks of seed cane from the storage pits], strip off the outer leaf sheath and cut them into setts approximately five or six *tshun*[2] [160–192 mm] long. As a rule leave two internodes (*chieh*[3]) per sett. Place [the setts] close together on the ground with the ends touching each other like scales on a fish, and lightly cover them with soil. Lay [each sett so that] both buds (*ya*[4]) are on a level plane and do not allow one to face up while the other faces down, as it will make it difficult for the [bottom] bud to germinate upwards. When the buds grow one or two *tshun*[2] [32–64 mm] high water them regularly with clear liquid manure (*chhing fên shui*[5]). After [the shoots] have grown to a height of six or seven *tshun*[2] [192–224 mm] dig them out with a hoe and transplant (*fên tsai*[6]) [them to the field].

This is the first reference in China to the practice of planting sugarcane setts in seed beds and transplanting them to the field after germination.[a] Agriculturalists placed setts very close together in a seed bed, exercising special care in placing the setts so that they can strike upwards and reach the light as easily as possible. They applied liquid manure after germination to enhance quick growth. This transplanting technique undoubtedly derived from ancient procedures of rice agronomy, which dated back to the pre-Han period. It is said to encourage tillering, facilitate weed and pest control, improve crop management, and give higher yields in rice than those attained by direct broadcasting.[b] With sugarcane the objectives are considerably broader. R. R. Panje and P. S. Gill have studied transplanting in modern north India and found that since transplants can be established well ahead of the normal planting season in sheltered gardens, the total growing season can be extended resulting in higher yields.[c] In this way it breaks the climatic barriers of cold and drought that precede the warm monsoonal weather and, in addition, improves germination and reduces the amount of seed cane required. These remarks directly apply to north of the ranges, and undoubtedly formed part of the philosophy of the Chinese innovators. But in recent times these considerations have led Chinese scientists to experiment south of the ranges in Kuang-Tung where large increases have been demonstrated from transplanting.[d] Modern pathologists have demonstrated that a soil-borne disease which affects germination, pineapple disease (*Ceratocytis paradoxa* [Dade] C. Moreau) is endemic in China.[e] In

[a] Tai Kuo-Hui (Tai (*1*), p. 72) suggested that the passage from the *TKKW* quoted above does not necessarily refer to transplanting from a seed bed to a cane field. He suggested that it described pre-germination, because with stalks measuring five *tshun* (16 cm) in length, seed beds would have taken up too much land and required extra labour. However, since the same passage also described planting in the fields as a separate process, with a distinctly different set of instructions from those for the first planting (three setts for every 2.17 metres), I find Tai Kuo-Hui's proposal hard to understand.

[b] Vol. 6, pt 2, pp. 277–9.

[c] Panje & Gill (1), see also Panje (1).

[d] Blume (1), p. 243.

[e] ISSCT Standing Committee on Sugar Cane Diseases, 1980–1983 (1), vol. 1, p. 51.

[1] 雨水 [2] 寸 [3] 節 [4] 芽 [5] 清糞水
[6] 分栽

badly infected fields it causes poor stands; however, this disease can now readily be controlled with mercurial fungicides.[a] Transplanting and the pre-germination techniques described below may have been practised in the past in fields badly infected with pineapple disease. The Chinese were the first to employ the transplanting technique as Indian, Arabic and New World sources did not mention it. Although recorded in the *Thien Kung Khai Wu* of +1637, the fact that Nieuhof failed to mention it in his *L'Ambassade de la Compagnie Orientalle des Provinces Unies vers l'Empereur de la Chine* of +1665 suggested that is spread quite slowly from about the late +16th century.[b] As this technique was mainly practised in the colder northern zones, sources for the southern zone and Chinese sugarcane-growing operations overseas did not document it, probably because the immigrants, who hailed from the southern zone, followed different methods. The early Chinese contribution in this area has passed unnoticed, and it is recorded in Hawaii and India as if invented in the 20th century.[c]

South of the ranges

South of the ranges, the mild, virtually frostless winters permitted the planting of bamboo cane, *chu chê* (*S. sinense*) in all situations for sugar production. This region, again due to the milder climate, enjoyed a greater variety of *S. officinarum* clones for chewing.

In the south, sugarcane was usually never killed by frost except in the foothills of the ranges and, as noted earlier, these were not recommended locations. The top part of the stalks unfit for milling were reserved for seed cane; these sections were stripped of leaf sheaths and chopped up into setts as normal. Various types of pre-planting regimes evolved, but they appeared rather late in history. This was unusual because the Chinese knew of the advantages of pre-germination of grain very early as Chia Ssu-Hsieh in his *Chhi Min Yao Shu* of c. +535 recommended pre-germinating wet and dry rice and hemp seeds,[d] and agricultural works after the Yüan dynasty mentioned pre-germination of vegetable seeds.[e] However, pre-germination of sugarcane setts before regular planting only appeared in the *Kuang Tung Hsin Yü* of +1700:[f] 'Soak the new ones [the cane setts] in water for a long time and wait for the buds to come out before planting. Plant in the first lunar month.' Higher winter/spring temperatures in the south permitted pre-germination by soaking in water in the Pearl River delta area and Taiwan.[g] Once again we can see climatic differences at work – in the

[a] Humbert (1), p. 106.

[b] Nieuhof (1), pt II, pp. 78–9, wrote: 'If [the sugarcane] is planted in furrows half a foot deep that are made, equally distant, with a hoe. A series of canes which are cut are layed in it and covered with earth. A short time after, each node forms a root which grows leaves and a shoot which produces in its time a new cane.' This indicates that pre-germination techniques were not uniformly practised in all the sugar-growing districts.

[c] Humbert (1), pp. 120–1.

[d] *CMYS*, 11/3/1 and *ibid.*, 8/2/6.

[e] Vol. 6, pt 2, pp. 247–9.

[f] *KTHY*, p. 689.

[g] Myers (1), p. 16.

northern zone the setts would not strike by soaking during late winter or spring, due to low temperatures. Soaking became a valuable technique because it did away with the need for striking the cane in seed beds, thereby reducing labour and making the seed beds available for the cultivation of other crops.[a] It is significant that the pre-germination soaking technique, which had been employed with wet rice and indigo from the +6th century,[b] should only appear in texts after the +17th century. From that time onwards, China began to experience a huge growth in population with resultant increased pressure on land, which in turn induced an intensification of traditional agricultural techniques.

(iii) *Land preparation, drainage and planting*

In sugarcane agronomy, the term 'land preparation' usually designates the operations necessary to make a seed bed, while 'planting' refers to the placement of seed in this bed. The earliest sources indicate that the Chinese never just fashioned their fields into flat seed beds, but first structured them in various ways, in preparation for planting at a later date. Such practices made furrows and beds prone to dry out, a situation which necessitated some form of irrigation on planting. The alternative of conserving moisture in well-prepared seed beds, and making furrows and planting after judicious falls of rain, only found favour after the +16th century in areas without facilities for irrigation.

North of the ranges

In the earliest account of sugarcane planting north of the ranges, the *Thang Shuang Phu* of c. +1154, cultivators practised the traditional Chinese method of ridges and furrows (*mu chhüan*[1]). *Mu chhüan*[1] was an ancient procedure first outlined in the *Lü Shih Chhun Chhiu*[2] of the −3rd century.[c] The *Thang Shuang Phu* recorded the preparation of sugarcane fields in early-to-mid +12th-century Ssu-Chhuan:[d]

After the eleventh lunar month deeply plough and harrow the cane fields [to break up clods of earth], and dry the soil lengthwise and breadthwise (*tsao thu tsung heng*[3]); harrow to fully prepare [the field]. As in opening a drain, make [furrows] over 1 *chhih*[4] [31 cm] wide and 1.5 *chhih*[4] [46.5 cm] deep, and build up ridges (*thu lung*[5]) on both sides [of the furrows]. Between the fifteenth day of the first lunar month and the beginning of the

[a] Soaking is valuable for two purposes, (1) pre-germination and (2) field establishment of the young plants. As regards (2), it should be noted that cane setts contain a considerable amount of air space that can be replaced with water. The water absorbed in the stalk aids in the field establishment of the young plants. (John Daniels, personal communication.)

[b] For rice, *WCNS*, ch. 10, p. 18b; for indigo, *CMYS*, p. 270.

[c] For details on the history of ridging in China see Vol. 6, pt 2, pp. 105–6.

[d] *TSP*, p. 3a; Liu & Liu (*1*), p. 14.

[1] 畎澮 [2] 呂氏春秋 [3] 燥土縱橫 [4] 尺 [5] 土壠

second lunar month, plant [the setts] in holes (*ou chung*[1]).[a] Lay the [cane] in rows with intervals between the setts (*hang pu hsiang chhan*[2]).[b] Cover the setts thinly with ashes and add not more than two *tshun* [6 cm] of soil.

Agriculturalists presumably fashioned the ridges and furrows with hand tools.[c]

The *Nung Sang Chi Yao*[3] (+1273) outlined a similar system from the Yüan period, though on a different time schedule,[d]

> Use rich and highly fertile soil (*fei chuang fên ti*[4]). Every year during the spring plough four times. The more you plough the better. Remove roots and weeds, and work the ground thoroughly ... Mounds (*chhi*[5]) should be 1 *chhih* [31 cm] wide. Soil at the places where [setts] are to be planted should be piled up slightly higher than the soil on either side[e] [within the furrow]. If the weather is favourable plant in the third lunar month. In the south where the climate is hot it is possible [to plant] in the second lunar month. When planting, [stalks of seed cane] should be cut into single setts five odd *tshun* [15 cm] long. [Each sett] should carry two or three buds (*chieh*[6]). [Sugarcane] germinates from the buds. Planting should be undertaken by laying the setts horizontally [in the furrows] at intervals of five *tshun* [15 cm], and covering them with two *tshun* [6 cm] of soil. Once planting is finished apply water, but only enough to moisten the setts. Do not inundate them.

The *Nung Sang Chi Yao* was a practical handbook compiled by order of the Yüan Emperor when he only occupied the northern Chinese provinces and some parts of Ssu-Chhuan. Regional variations in agricultural practices due to the effects of cold weather in areas above latitude 30°N were amply reflected in the injunction to plant in the third lunar month, one to one and a half months later than the planting date recommended in the *Thang Shuang Phu* of c. +1154. This passage provides important information on the length of the setts and number of buds to be planted, details omitted from *Thang Shuang Phu* (for details on germination see Figs. 35, 36 and 37). The *Nung Sang Chi Yao* also displayed accurate knowledge of sugarcane germination by stating that it struck from the buds, and the advice that each sett should have two or three buds, and not be covered with too much soil clearly amounted to very sound agricultural practice.

The texts were not specific, so we must speculate as to whether scratch or

[a] The step sides of the ridges probably allowed soil to collapse into the rows; at planting a hole was dug to plant the cane at the original depth of the furrow. I have reconstructed this procedure from Egyptian practice with a similar system, the Reynoso, see below and van Dillewjin (1), p. 21.

[b] The phrase *hsiang chhan*[7] literally means, 'mutually not in order', which I interpret to indicate not placing the setts in rows with the ends touching each other, but leaving spaces between each sett. Instructions concerning the distance between setts appeared in the *NSCY*, ch. 6, pp. 13b–14a and the *TKKW*, p. 163.

[c] See Vol. 6, pt 2, pp. 138–9 for basic types of ploughs and their attributes.

[d] *NSCY*, ch. 6, pp. 13b–14a.

[e] That is the furrows should be deepened where the setts are planted.

[1] 區種 [2] 行布相儭 [3] 農桑輯要 [4] 肥壯糞地 [5] 畦
[6] 節 [7] 相儭

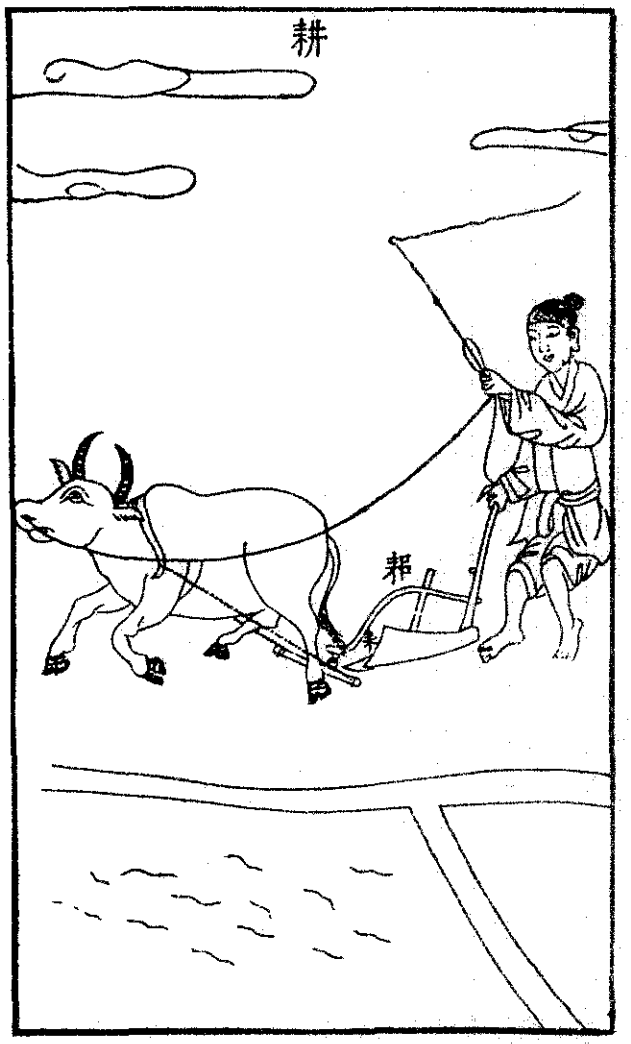


Fig. 41. A scene of ploughing from the 1959 Chung Hua reprint of the original +1637 edition of the *Thien Kung Khai Wu*, ch. 1, p. 6b. The artist has idealised the situation to show the parts of the plough, rather than illustrating the act of soil being turned over to make furrows. The operational parts are clearly visible; the share with mould-board attached, the strut which controls the depth of ploughing, and the whipplechase which enables the ox to draw the plough.

mould-board ploughing was involved (see Figs. 41, 42 and 43). It has been shown in Volume 6, part 2 that the mould-board plough dated back to at least Han times. It reached its present form in a description in Lu Kuei-Mêng[1]'s *Lei Ssu Ching*[2] of c. +880. The *Nung Shu*[3] of +1313 discussed the two types of plough for general cultivation and stated that 'nowadays' agriculturalists in the north usually applied the mould-board share (*hua*[4]), while those in the south univer-

[1] 陸龜蒙 [2] 耒耜經 [3] 農書 [4] 鏵



Fig. 42. A +17th-century European single-wheel, mould-board plough ploughing a field. Notice the large cumbersome mould-board. The Chinese used a light curved mould-board, swing plough to control weeds in inter-rows. One pass of the plough shaved soil and weeds away from one side of the cane row, and this was followed by a second pass down the centre of the same inter-row throwing the soil back towards the row. This procedure was repeated as necessary until the cane leaves covered the inter-rows: detail from The Fall of Icarus by Pieter Brueghel the Elder (+1525 to +1569), through Craven (1), p. 119.



Fig. 43. An Islamic scratch plough of the +16th century. This plough literally scratches the surface and a large number of passes from different directions are necessary to gain tilth and eliminate weeds, but it conserves moisture on arid lands; from the British Library through al Hassan & Hill (1), p. 207, fig. 8.3.

sally used the scratch share (*chhan*[1]).[a] By the time of the *Nung Sang Chi Yao* of +1273 the mould-board plough probably attained more general use, as indicated in the *Nung Shu*.[b] But neither the *Thang Shuang Phu*, nor the *Nung Sang Chi Yao* explained exactly how agriculturalists constructed the ridges and furrows. The description given in the *Nung Sang Chi Yao* is not incompatible with the hypothesis that they performed all preparation with a mould-board plough. It would appear that the inter-rows, that is the distance between row centres, measured 31 cm at a minimum. This roughly approximated to a configuration used for ridge and furrow in general agriculture in north China in the 20th century.[c]

In Volume 6, part 2 the close relationship between the method of ridges and furrows (*mu chhüan*[2]) and the 'changing fields' (*tai thien*[3]) of Chao Kuo[4] (−1st century), in which the ridges of one crop cycle become the furrows of the next,[d] was noted. Though the *Thang Shuang Phu* only provided a sketchy description of field management, it was obvious that in most cases, other crops were planted in a field after a single crop of sugarcane, thus preventing ratooning. As the cane root stocks would have to be dug out or ploughed out in rows, it would be natural to alternate the new crop into the inter-rows of the cane crop.

Here we come again to one of those worrying cases of possible diffusion. 'Free' Chinese labour arrived in Cuba in 1847 and proved more successful than black slaves. A short while later Don Alvaro Reynoso wrote his influential *Ensayo sobre el Cultivo de la Caña de Azúcar* in 1862.[e] The system he expounded seems pure Chinese agriculture, but we must note that it could have developed from the New World trenching systems discussed earlier. Peasants dug trenches (rows) to a depth of about two feet and piled the soil into mounds in the inter-rows. They loosened the soil at the bottom of the row trenches with a hoe or fork, or added some of the inter-row soil to the furrows at planting, placed cross drains for irrigation and gradually hilled soil onto the rows as the crop progressed. In the next crop cycle, they dug out the cane and then prepared the land so that the former row now served as the inter-row, which was precisely the 'changing fields' (*tai thien*) of Chao Kuo. A Dutch translation of Reynoso appeared under the title *Verhandeling over de Cultuur van Suikerriet* in 1865, and became 'the Bible' of the Dutch in Java, who developed the most technically advanced and economically successful plantations in the world during the late

[a] See especially Vol. 6, pt 2, pp. 169–86.

[b] It is likely that there was a prolonged transition from scratch ploughing to mould-board ploughing because under the dry conditions of central China the difference favouring the mould-board plough was probably marginal. The scratch-type plough was employed in the Middle East, an arid area, for thousands of years until the 20th century. Mould-boards were introduced with tractors, but had to be abandoned for tynes and discs, because inverting the furrows caused serious losses of soil moisture, which was minimised with scratch ploughing, see al-Hassan and Hill (1), p. 208.

[c] See quote from King in Vol. 6, pt 2, p. 106. King makes it quite clear that these narrow ridges and furrows were common in north Chinese agriculture.

[d] See Vol. 6, pt 2, p. 105.

[e] For the essence of his system see Reynoso (1), pp. 60–73.

[1] 鐅 [2] 畎澮 [3] 代田 [4] 趙過

19th and early 20th centuries. The Dutch modified the Reynoso method to enable rice and sugarcane to be rotated approximately yearly in paddy fields. After harvesting the paddy rice, deep trenches were dug with shovels, the soil piled into the inter-rows for drying out and the cane subsequently planted.[a] It is ironic that the Reynoso system never found followers in Cuba, the land of Reynoso's birth, and he died in poverty in 1888.[b] However, 20th century agronomists employed it to advantage in Egypt,[c] Turkey[d] and possibly other countries; see Fig. 44 which shows a Reynoso sugarcane field in Turkey, and compare it with Fig. 45, a field ridged in the Chinese manner. The similarity is most striking and the methods only differed in the distance between row centres, which were greater in Egypt with 71–80 cm, in Turkey at 1 m, and in Java at 90–145 cm. In 1929 the International Society of Sugarcane Technologists discussed the Reynoso method in Java, and participants pointed out that similar systems had been adopted in the Philippines and Taiwan.[e] I shall show below that these methods formed part of the technological package transferred overseas from China after the late +16th century, which included the Chinese mould-board plough, agricultural systems, and processing equipment with technical expertise.

The ridge and furrow system practised in the Yüan dynasty and later, had very narrow inter-rows of 31 cm at a minimum, contrasting with recommendations of 1.5 to 1.8 m by modern tropical agronomists.[f] Closer row spacings were practised traditionally in India[g] and the Islamic world as has been noted previously. W. J. Brzesowsky has provided the solution to this paradox in showing that the crucial factor is length of the growing season.[h] Areas with short growing seasons, as in the temperate sub-tropical zones, should have closer spacings so that the ground is covered by leaves as rapidly as possible to give the plants a longer period for receiving and utilising solar radiation.[i] In the tropics, with longer growing seasons, stalks die through competition for light and re-

[a] See Deerr (2), pp. 129–30 and pl. 15 for a description of the Reynoso system, particularly as applied in Java. The Javanese system is described in greater detail in van Dyk (1).

[b] Fraginals (1), p. 91; Deerr (1), p. 586.

[c] van Dillewjin (1). The methods described are not identified as Reynoso, this is my interpretation.

[d] van Dillewjin (2).

[e] See discussion in van Dyk (1), pp. 271–3.

[f] Humbert (1), pp. 112–15. Blackburn (1), p. 148. Bull (1) has noted that these recommendations apply to mechanically cultivated fields with clones that have been selected using these inter-row spacings. He suggested that higher yields could be obtained by closer row spacings with clones that were specifically selected using closer row spacings. It has been shown that irrigated fields can support more stalks where wide spaces are normally allowed, and rows can be as close as 1 m, see Thompson and du Toit (1).

[g] Modern experimentation in India supports optimum spacings of 60–90 cm, see Singh and Singh (1) and Mali and Singh (1).

[h] Brzesowsky (1).

[i] These theoretical considerations may have to be modified by economics in practice, because the closer the crop is planted, the more seed cane is required. Stubbs ((2), p. 112) put the position succinctly in describing the results of his experiments in 19th-century Louisiana: 'In almost every instance the narrower the row, the larger the yield of cane without injury to the sugar content or its purity. But while the increase in the very narrow rows has been quite apparent, the increments have hardly paid for the increased seed used in planting.' Stubbs recommended selecting a row spacing convenient for the efficient working of the equipment available.



Fig. 44. A field prepared for planting sugarcane by the Reynoso method in 20th-century Turkey. Deep trenches are dug, throwing the soil onto the inter-rows. The trenches are 10 m long, 20 cm deep and 40 cm wide and the distance between the centre of one trench and the next is 1.0 m. The cross drains every 10 m allow the field to be flood irrigated or drained at will. The sugarcane is planted in the trenches and the soil gradually added. Compare with Fig. 45; from Van Dillewijn (2), p. 5, fig. 5.



Fig. 45. A field prepared for planting ginger by the Chinese ridge and furrow system in 20th-century China. Sugarcane was planted in a similar manner with furrows constructed at 60 cm between centres. This was the usual system for planting sugarcane in the northern sugarcane-growing zone of China prior to the +17th century, after which it continued side by side with the method of using wider furrows made with a mould-board plough. Compare with Fig. 44; from King (1), p. 91, through Vol. 6, pt 2, p. 112, Fig. 28.

sources.[a] The different practices of pre-modern China with row spacings of 31 cm north of the ranges and up to 1.28 m south of the ranges were in line with the best modern advice.[b] Elsewhere in the pre-modern world, such as in India with broadcast planting and in the Islamic world with 50 cm spacings, the rows remained too narrow.

The +17th century marked a most important point in the history of Chinese and world sugarcane agriculture for it saw the documentation of a new regime in the *Thien Kung Khai Wu* of +1637. Row spacings increased from about 31 cm to 1.28 cm to allow the cultivation of sugarcane with the mould-board plough after establishment. The transplants were planted in furrows about 12 cm deep between preformed ridges. Cultivation commenced after the young plants were established by ploughing away from the cane rows with a mould-board plough. Subsequent ploughing in the inter-rows controlled weeds, and when the leaves closed in over the cane rows deep furrows were made in the centre of the inter-rows, and the soil hilled up on the cane rows.[c] The *Thien Kung Khai Wu* explained:[d]

> When planting sugarcane make raised mounds in lines (*chhi hang*[1]) 4 *chhih*[2] [1.28 m] wide, and plough furrows 4 *tshun*[3] [12.8 cm] deep. Plant the cane [transplants] in the furrows, three transplants (*tshung*[4]) for every seven *chhih*[2] [2.24 m] and cover them with a *tshun*[3] [3.2 cm] or so of soil. If too much soil is added, fewer shoots will strike [the subsequent passage on cultivation is cited below].

Wider spacing of plants in a row reduced the potential shoot population density; the interval between setts of roughly 15 cm in the *Nung Sang Chi Yao* was increased to approximately 32 cm in the *Thien Kung Khai Wu*.[e] Agriculturalists only ploughed a very shallow furrow between the mounds prior to transplanting, and they presumably opened them up at the time of planting to reduce loss of moisture.

It is possible that the increase in row width from a minimum of 31 cm to 1.28 m at this time may have been activated by a shift towards intercropping, which developed in response to the contemporary intensification of agriculture. One would certainly expect the distance between cane rows to vary according to the type of plant being intercropped, and the drainage requirements created

[a] In all fields, even with wide spacing, more stalks are produced *early* than will survive *at maturity*: the shoots compete for light, and weak and feeble stalks die; shoot mortality rates of 50 per cent or more are considered normal, for example see Thompson & du Toit (1), p. 109, fig. 3.

[b] This expresses the ideal situation, and of course in reality agriculturalists north and south of the ranges deviated from this ideal.

[c] In sugarcane agriculture parlance the term inter-row refers to the distance from the centre of one row (furrow) to the centre of another row. Therefore an inter-row of one metre is measured from the centre of one row to the centre of another row, and not from the ridge or any other point.

[d] *TKKW*, p. 163. The interval between the sets for *TKKW* was roughly calculated from figures given in the *TKKW* text quoted below.

[e] Also consider the fact that with pre-germinated plants, every unit placed in the field is a strike, while with sett plantings there will be some misses, and closer planting will ensure a complete stand.

[1] 畦行 [2] 尺 [3] 寸 [4] 叢

by different rainfall conditions. After harvesting the intercrop, the mould-board plough would be an ideal instrument for removing the intercrop residues, controlling weeds and regaining tilth. This may have been the genesis of the inter-row cultivation system discussed below. Agriculturalists retained the old closer row spacings as a major concurrent system, and both wide and narrow rows came down to the 20th century. The choice between narrow rows with hand hoe cultivation, versus wider rows with mould-board plough regimes, was probably governed by factors such as the pressure to intercrop, availability of oxen, excess of human labour and soil type coupled with topography.

South of the ranges

Several factors operating in the south made sugarcane planting a different operation than in the north. First, seed cane was available year round. Nevertheless, as seed cane can amount to over 10 per cent of the total yield, it proved more economical to plant from 'tops' in late winter/spring near the harvesting time of mature cane. With late winter/spring planting, the growing period for plant cane extended considerably longer than north of the ranges, where cane was planted in the late spring. Second, with higher rainfall and flat land, considerable attention had to be paid to proper drainage. In the north the rainfall was lower, and the flat land often limited to raised areas deeply dissected with rivers seven to ten metres below field level; there were no drainage problems on this land. In the south, the most elementary form of drainage control, probably dating back to the prehistoric Yüeh communities, was to plant sugarcane on simple mounds. This drainage strategy persisted until the +18th century at least, since A. Duncan, surgeon to the English factory at Canton reported it to Richard Hall in India when he dispatched samples of *Saccharum sinense* to the Calcutta Botanical Gardens in +1796:[a]

> The culture of sugar canes commences about the middle of March or beginning of April, in proportion to the temperature of the weather, when a good, light sandy soil is thrown up into beds about four feet diameter leaving intermediate spaces of one and a half, which serve as drains and passes for the husbandman. A composition of human manure and water is thrown over the beds; after which tops of sugar canes, fifteen inches long (the Chinamen are born economical) are planted in a slanting position ... [see Fig. 46].

Pierre Poivre in his *Voyages d'un Philosophe* ... of +1768 described similar planting methods for Vietnam:[b]

> When the Cochin-Chinese prepare the ground for the sugar-cane, they turn it up to the depth of two feet; this operation is performed with a plank. They then plant joints or eyes of the cane, three and three together, in a horizontal position, almost in the same way as they plant vines in many French provinces. These slips are planted

[a] Roxburgh (1), vol. 3, p. 27.
[b] Poivre (1), pp. 106–7.

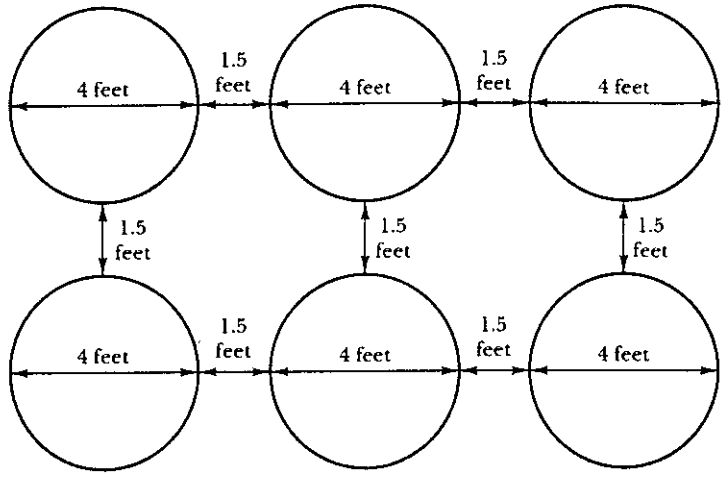


Fig. 46. A plan drawing of a sugarcane field showing the method of planting on mounds or squares in the southern growing zone of China prior to the transfer of furrow and ridge planting in the +17th century. This was an aboriginal system of planting, and was also observed in +18th-century Vietnam by Poivre ((1), pp. 106–7), who mentioned planting sugarcane in chequerboards 6 feet apart; drawing from description in Roxburgh (1), vol. 3, p. 27.

chequer-wise, about eighteen inches deep in the ground, six feet distant from each other; they perform this operation towards the conclusion of the rainy season, so that the slips may be sufficiently watered till such time as they have taken root.

In 1882, over one hundred years later, the American Consul at Canton reported sugarcane planted in rows two feet apart using tops with bean cake fertiliser applied at planting. In the intervening period ploughing methods from north of the ranges had been adopted. Cultivators dug deep drains around fields, added cross drains to make large raised beds, and applied the traditional methods of ridge and furrow developed north of the ranges to cane planted on these beds. They broke up the soil from the drains and piled it onto the ridges of the cane rows.[a] Some modifications based on traditional methods also appeared, such as planting sugarcane on top of the ridges, rather than in the furrows in areas with bad drainage. In the present day Pearl River delta area sugarcane is planted on the ridges and soya beans and peanuts in the furrows.[b]

As noted earlier, sugarcane cultivation expanded from the valley floors onto less favourable land after the +16th century. Drainage did not constitute a major problem in these areas, and agriculturalists planted fields using traditional closer spaced ridge and furrow regimes, adopting terraces where appropriate. We shall discuss below a hypothesis that Fukienese immigrants introduced these methods into Kuang-Tung during the +17th century along with

[a] There is a lengthy description of the variations on this theme in a Chinese survey conducted in the Pearl River delta in the 1930s, Anon (*550*), p. 29; a Japanese translation, Kōain Gijutsubu (1), pp. 39–40 is erroneous in places.

[b] Blume (1), p. 243.

improved methods of manufacture. These methods have continued to the present time as reported by an Australian agricultural mission of 1979, which studied agriculture in large State farms in Kuang-Tung.[a] They found 'traditional' agriculture on terraced land; cultivators used cane tops for planting, which they planted in rows 0.9 to 1.0 m apart, and opened the rows with two passes by ox-drawn, mould-board ploughs. On flatter land methods were similar, except that tractors had replaced oxen power for most operations.

Seed cane placement on planting

We will now consider an important problem which appeared north and south of the ranges: should cane setts be planted horizontally or vertically? The *Nung Sang Chi Yao* of +1273 instructed: 'planting should be undertaken by laying the setts horizontally (*wo tsai*[1])'. The *Chih Fu Chhüan Shu* of +1620, another source for central China, also recorded 'horizontally laying (*wo*[2]) the setts in the furrows',[b] and Sung Ying-Hsing[3] wrote: 'lay [each sett so that] both buds are on a level plane, and do not allow one to face up while the other faces down'. Both of these passages referred to the same practice.[c] Nevertheless, later Chinese and European sources for south China, particularly Kuang-Tung, documented a different practice. For instance, the *Kuang Tung Hsin Yü* of +1700 stated: 'Sugarcane must be planted in the second lunar month of the year by slanting the setts (*hsieh chhi ken*[4]). By slanting the setts, later many shoots will come out of all sides (*shu chhu*[5]) of the sugarcane.'[d] The difference between horizontal and slanted or vertical planting is largely a matter of precipitation levels. In the northern zone, which received relatively less rainfall than the southern zone, sugarcane was planted horizontally. In the southern zone, especially in rice fields, moisture is often too high and sometimes cannot be controlled, because of high rainfall. If the cane setts were planted horizontally and the field became too moist, all the buds would be killed because they are on the same level, whereas if planted vertically, the top bud would strike even if the bottom buds were killed by excess moisture (see Figs. 47a and 47b). If by chance there was a drought in the wet zone then the bottom bud would strike. In the Fiji Islands cultivators planted horizontally on the dry western side of Viti Levu and largely vertically on the wet eastern side at Nausori.[e] In short, though horizontal planting is ideal because it allows all shoots to strike and grow straight,

[a] Australian Sugar Mission to China (1), pp. 41–2.

[b] *Chih Fu Chhüan Shu*, ch. 5/*chê*. The same line occurred in the *Chih Fu Chhüan Shu* of +1678 ch. 1, p. 26a.

[c] *TKKW*, p. 168. Since the buds occur at each node and alternate from one side to the other going up the stalk, with horizontal planting the buds must be put on the sides. If one bud is on top, the next bud will be positioned on the bottom and it will be difficult for the bottom bud to strike. The best strategy for planting with one-eye setts is not to have the bud on the side but on the top, so that it can grow straight up.

[d] *KTHY*, p. 689. Roxburgh (1), vol. 3, p. 27 recorded planting 'in a slanting position'.

[e] John Daniels, personal communication, April 1988.

[1] 臥栽 [2] 臥 [3] 宋應星 [4] 斜其根 [5] 煞出

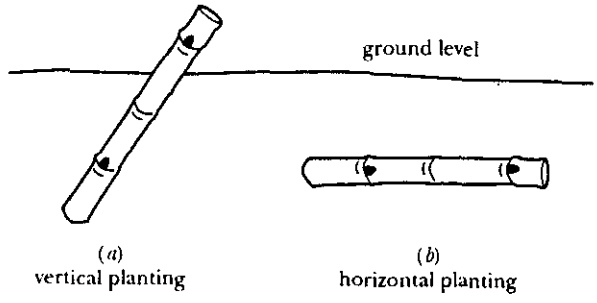


Fig. 47*a*. A three-eye sett planted vertically. This method is practised in badly drained conditions, or in areas of high rainfall. There are three eyes on the sett; one eye below ground, one at ground level and one above, providing three chances of striking depending on water levels.

Fig. 47*b*. The usual method of planting horizontally in a furrow. In wet conditions all eyes may be killed through waterlogging. Note that buds are planted with the eyes on the side, so that the buds on each side of the stalk have an equal chance of striking.

under high moist conditions vertical planting reduces the failure rate by guaranteeing that at least one of the buds strikes.[a]

(iv) *Weed control and inter-row cultivation*

Most sugarcane areas in the world face serious weed control problems. The first step in control involved meticulous preparation of seed beds, and we have seen that in most countries agriculturalists ploughed seed beds a number of times, which considerably reduced weed populations prior to planting. After planting the cane 'strikes', and the young cane leaves progressively close in over the inter-rows. The closer the rows are together, the quicker the cane will close in, and the time between planting and closing in is critical for establishing a good crop. The traditional method of weed control in the northern and southern zones was removal of all weeds by hoe with concurrent aeration and turning over of the soil. However, cultivators north of the ranges developed mechanical methods for inter-row cultivation. They used the mould-board plough to ridge the sugarcane high, still a characteristic feature of Chinese sugarcane agriculture today, especially in the typhoon zone where the crop is prone to wind damage.

North of the ranges

When we earlier examined the first northern zone reference for sugarcane agriculture in the *Thang Shuang Phu* of c. +1154 we found the cane rows arranged very close together, the inter-row measuring about 31 cm (see p. 214,

[a] With slanted or vertical planting the shoots tend to grow out at tangents and therefore lean over at angles and are easily damaged during cultivation. This defect must have been offset by the reduction in the failure rate of strikes it ensured.

above). Inter-rows of this width made mechanical cultivation with oxen difficult. The *Thang Shuang Phu* provided an account of the methods practised:[a]

Never weary of [hoe] weeding and adding soil [to the cane rows] several times, but [always] ensure that the shoots are constantly exposed [above the soil]. Later when the [sugarcane grows] taller and forms clumps, employ a big hoe to turn over [the top soil] on the ridge, [and use it] to completely cover [the cane row] (*yung ta chhu fan lung-shang-thu chin-kai*[1]).

As well as weeding, cultivators gradually moved the soil from the inter-row ridges onto the sugarcane in the furrows with hoes, and the final operation involved hilling the sugarcane with soil from the inter-row. This hilling operation aimed to prop up the cane and keep it erect until harvest time, as well as to protect the roots from cold weather for better ratooning after harvest. Henry Botham reported that this operation was performed by traction spade on the European plantations on Sumatra which contracted Chinese labour during the +18th century.[b] As the traction spade was traditional Chinese equipment, it is reasonable to suppose that Chinese agriculturalists regarded it as too common to warrant special mention in their texts.

Earlier we saw that by the time of the *Thien Kung Khai Wu* of +1637, the width of the cane rows had doubled in some areas. However, the wider rows presented additional weed control problems since the sugarcane took longer to close in. This text described methods of overcoming the problem:[c]

After three, four, six or seven tillers have germinated gradually ridge, and add soil [to the cane rows] when hoeing and weeding. As the banked up soil progressively gets thicker, the stalks grow taller and the roots sink deeper, thereby avoiding the danger of the cane stalks bending over. You can never be too diligent in hoeing and weeding ... When the setts reach a height of two or three *chhih*[2] [64–96 cm] an oxen is used to plough between the rows (*nei keng*[3]) twice a month. First use the plough to turn the soil and cut the side roots, then bank the soil up on the root base. At the beginning of the ninth lunar month, pile soil on the roots to protect them against damage from frost and snow after cutting.

This source divulged the first knowledge of inter-row cultivation of sugarcane with the mould-board plough, which signalled the advent of a method that formed the basis of modern cultivation with animal- and tractor-drawn implements. The method essentially consisted of running the mould-board alongside cane rows thereby throwing soil away from the cane onto the inter-row (ridge); this operation effectively widened the furrow and increased the height of the ridge. It also pruned the roots, an operation which some agronomists still con-

[a] *TSP*, p. 3b; Liu & Liu (*1*), p. 14.
[b] East India Company (*1*), p. 84.
[c] *TKKW*, pp. 163–4. The last line of this passage must refer to ridging to protect the rootstock left in the field when ratooning.

[1] 用大鋤翻壠上土盡蓋　[2] 尺　[3] 內耕

sider useful for promoting tillering and new root growth as long as it does not become too drastic.[a] Cultivators then ran the mould-board down the centre of the inter-row (ridge) each way, throwing the soil back onto the rows (furrow). They repeated this operation as a weed-control measure, and to reshape the field; the ridges disappeared as they gradually threw the soil onto the rows. Additional passes with a small, toothed harrow or scarifier aided in flattening the ridges and in weed control. Finally they made a furrow in the former inter-row by running the mould-board down the middle of the row in a deep pass each way. This enabled the hilling, previously done with hand hoes (see *Thang Shuang Phu* citation, above), to be undertaken by mechanical means, as well as providing a furrow for continued irrigation. This technique was not an independent development of Chinese sugarcane agriculture; as previously related in Volume 6, pt 3, horse-hoeing husbandry, an ancient Chinese strategy, probably dated back to the +2nd century.[b] The innovation in this case was the application of the common mould-board plough as a regular horse-hoe, thus minimising capital investment on sugarcane farms. The sole disadvantage with this regime was that the animal-driven mould-board plough cannot get in between the rows once the cane growth gets too thick.[c] Nevertheless the advantages outweighed the disadvantage. First, the mould-board plough had the ability to turn over substantial furrows as an aid in smothering weeds. Second, it could reshape the inter-row ridge into an irrigation channel and hill-up the rows. Third, and more importantly, it saved more labour than hand-hoeing. From the viewpoint of modern mechanical cultivation the *Thien Kung Khai Wu* technique showed a highly developed knowledge of sugarcane agriculture well in advance of the contemporary cultivation practices in the European New World colonies. In fact, these basic principles of tending to sugarcane in the field are what 20th-century extension workers recommend to growers using mechanical cultivation techniques today.

South of the ranges

We have little direct knowledge of weed control in south China, but it is obvious that with the traditional method of planting cane on top of raised mounds

[a] It is widely practised in the modern world and is not considered deleterious, cf. Humbert (1), p. 443. Care must be taken in dry weather not to expose the stool roots. Farmers and extension workers in the Fiji Islands consider that it promotes tillering and new root growth, John Daniels, personal communication, 1988.

[b] Vol. 6, pt 2, p. 310.

[c] In August 1989 local officials interviewed at Sha-Wan Chen[1], Pan-Yu county[2] near Kuang-Chou[3] stated that cane growers preferred the mould-board plough because it was faster than a hoe and saved more labour, but at the same time pointed out that heavy sugarcane growth was an important criterion for choosing between the plough and the hoe. They said that at present cultivators growing sugarcane on paddy land always ridge it with hoes, while those planting on dry land ridge with hoes for the first two times, and with a mould-board plough on the third occassion in July or August, when the rows have to be built up to protect the cane from typhoon damage.

[1] 沙灣鎮 [2] 番禺縣 [3] 廣州

in the wetter areas, weed control must have been performed entirely by hand with hoes or some such instruments. In fields well drained with beds and deep drains, and in terraced fields, the two-feet inter-rows meant that the cane leaves would close in rapidly and control of weeds by hoe would be effective.

We now confront an interesting problem. The discussion so far, shows that agriculture south of the ranges around Canton and the Red River delta in north Vietnam was largely a continuation of the Yüeh systems until the 19th century. However, adjacent to these areas in Fukien, on the border of the northern zone, Chinese agricultural methods were exported overseas. I surmise that the Fukienese probably adopted the northern zone methods sometime in the +16th century, and conveyed them to Kuang-Tung as well as overseas during the +17th century. Alternatively Fukien may have been the centre of innovation and the new mould-board methods spread north and south from there. The methods practised overseas express the full potential of the Chinese techniques as they were employed on larger-scale operations in European plantations in South-East Asia.

Agronomy of overseas Chinese managers

For the account of overseas Chinese sugarcane agriculture given here I rely on Henry Botham who observed Chinese agriculture first hand at Bencoolen, Sumatra c. +1770. Immigrants transferred Chinese agriculture and sugar-making technology to countries in East and South-East Asia after the late +16th century. Botham had experience of sugarcane agriculture in the East and West Indies and testified before an English commission on slavery, where he described how the Chinese managed plantations.[a]

> The cane is cultivated to the utmost perfection at Batavia. The hoe, almost the sole implement of the West, is there scarcely used; the lands are well ploughed by a light plough with a single buffalo, a drill is then ploughed, and a person with two baskets filled with cane plants, suspended to a stick across his shoulders, drops into the furrow plants alternately from each basket, covering them at the same time with earth with his feet. Young canes are kept often ploughed, as a weeding, and the hoe is used to weed round the plant when very young; but of this there is little need if the land has been sufficiently ploughed. When the cane is ready to earth up, the space between the rows is ploughed deep, the cane tops tied up, and an instrument like a shovel, with teeth at the bottom, a spade handle, and two cords fixed to the body of the shovel, ending by a wooden handle for a purchase, is used by two persons to earth up the cane, the strongest holding the handle of the shovel, pressing it into the ploughed earth, while the other, on the opposite side of the plant, by a jerk of the cord draws up to the plant all the earth that the plough had loosened. Two persons with this instrument, will earth up more canes in the day than ten negroes with hoes. The canes in India[b] are much higher earthed than in the West-Indies; in moist soils they, with little labour, earth

[a] East India Company (1), p. 84.
[b] I.e. the East Indies.

them as high as the knee, at once making a dry bed for the cane and a drain for the water.

Botham then outlined the sugar-manufacturing process, which we consider later, and philosophised on the difference between free labour with mechanical aids such as ploughs versus slaves with hoes. He concluded that 'the West-India planter, for his own interest, should give more labour to beast and less to man ... By this means following, as near as possible, the East-India mode, consolidating the distilleries, I do suppose our sugar-islands might be better worked than they now are, by two-thirds, or indeed one half of the present force.' This was at once a testament to Chinese agricultural technology, and the first expression of a point to which we shall return, that the Chinese injected a large measure of managerial competence into their operations. They proved themselves competent 'agribusiness managers', using contract labourers drawn from among the ranks of their countrymen. Notice how they organised all operations for continuous large-scale operations; they opened the rows as required thereby preventing loss of moisture by leaving them open constantly, and carrying cane setts prepared elsewhere in baskets they worked continuously, planting them by dropping and positioning with their feet while walking. They conducted as much as possible of the succeeding operation with the mould-board plough.

Apart from these considerations, this detailed account by Henry Botham explained a point obscure or missing from the Chinese texts. The *Thang Shuang Phu* of c. +1154 remarked of hilling, 'use a big hoe to turn over [the soil] on the row, completely covering [the cane row] with top soil from the ridges' for the final operation after the cane closed in.[a] Botham made it clear that agriculturalists hilled up the cane with a spade or hoe pulled by a rope (see Fig. 48); such an instrument, the *chhiang li*[1] has been reported in modern Shan-Hsi.[b] Again note that this labour-minimising operation made good management practice.

Readers must realise that for contemporary political reasons Botham strove to emphasise the point that slavery was an uneconomic as well as a pernicious practice and, in doing so, portrayed an idealised system that probably included the best of current practice. This becomes apparent when we compare Botham's account with that of another admirer of the Chinese labour-management system. Leonard Wray, on the basis of personal experience in Province Wellesley, on the north-west coast of the Malay peninsula, during the 1840s advocated the use of contract Chinese labourers in the West Indies after slave emancipation. European plantation owners in Province Wellesley contracted Chinese managers to clear virgin land and to cultivate and harvest sugarcane for them. The Chinese managers received payment either by the area of land,

[a] *TSP*, p. 3b.
[b] Vol. 6, pt 2, p. 149.

[1] 鏘 or 搶 · 犁



Fig. 48. A production team on a collective farm in China using a *chhiang li* or traction spade. This tool is most useful for hilling up sugarcane rows, and vastly increases human productivity; from Blunden & Elvin (1), p. 211.

or by the weight of sugar produced from the land under their care. They supervised Chinese labourers, whom they employed on their own account, to undertake the work with hoes.[a] Wray claimed that the system of contracting out the section of a plantation to Chinese labourers who worked with hoes was more efficient than using slave labour, and especially praised the method of payment according to weight of sugar manufactured.[b]

> Wherever the interest of the cultivator is not directly implicated, the planter has no assurance of his cordial co-operation; there is an absence of that fellowship, which so greatly relieves the planter's anxious mind, and is so necessary to success: that fellowship created by a common interest, a mutual risk, and a mutual hope of profit.
>
> Thus the contractor finishes his job, and his men leave the field, quite indifferent whether it be destroyed by fire, eaten down by wild elephants, robbed by human prowlers, or in any way injured, an hour afterwards. Indeed if they were to see bundles of canes being cut and taken away, they would not consider themselves called on to act as policemen to the estate, or even to volunteer information against robbers; not they. But under contracts by the picul, woe betide the unlucky quadruped, or biped, caught trespassing by the contractor or his people.

His experience highlights an important point which helps us understand the role of the plough and hoe in Chinese agriculture. The Chinese managers in

[a] For advocation of use of Chinese contract labour in the West Indies see Wray (1), pp. 106–12, and for an account of the situation in Province Wellesley see *ibid.*, pp. 124–44.

[b] *Ibid.*, p. 140.

Province Wellesley had their labourers use hoes for cultivation work, and opposed the introduction of ploughs drawn by elephants as they thought roots, stumps and other impediments in the newly opened fields made their application cumbersome. This illustrated that the choice of the mould-board plough, instead of the hoe, for land preparation and inter-row cultivation was determined by soil conditions, availability of labour and extent of crop growth rather than pure technology. We can conclude that the Chinese both at home and abroad employed the hoe when labour was abundant and the mould-board plough in situations where it was scarce, and as a general rule the contracting system acted as an incentive for the labourer to work harder than slaves.

(v) *Irrigation*

During the early 19th century, English planters in the West Indies and Ceylon attributed the excellence of Chinese sugarcane to superior methods of irrigation.[a] Chinese diligence in this area was well placed as sugarcane needs large amounts of water to grow an economically viable crop, as can be gauged from the folklore that 60–70 tons of irrigation water must be applied to produce each ton of cane.[b] Alternatively, it is said that sugarcane needs a precipitation level of about 1,200 to 1,500 mm to grow a crop with a reasonable yield.[c] As precipitation south of the ranges varied from 1,200 to 2,000 mm, at first sight it appeared that sugarcane could be grown without supplementary irrigation. However, distribution and evaporation were important subsidiary factors, and Blume brought them out in the climatic boxes on his map (see Fig. 32) and in his text.[d] The data indicated probable drought level deficits in autumn, and in some areas in spring as well. The position was worse north of the ranges with precipitation levels in the order of 1,000 to 1,100 mm, with deficits in spring and autumn. There were four methods of irrigation for sugarcane: basin (paddy, flood), border beds (sub-irrigation by adjusting the water-table), furrow irrigation by row and furrow irrigation by inter-row.[e] All four methods have been adopted for sugarcane in China.

North of the ranges

North of the ranges the total precipitation received lies in the order of 1,000 mm, with an unequal distribution requiring irrigation in spring and autumn. The potential water stress is only mitigated by the arrival of the monsoon. In addition, the methods outlined earlier, in which ridges and furrows were

[a] Sirr (1), vol. 1, p. 334.

[b] Babu (1), p. 177. R. A. Yates (Yates (1), p. 81) has summarised work in many countries where production rates reported were all 1 tonne ±0.2 tonne cane/ha per cm of evapotranspiration.

[c] Blume (1), p. 45.

[d] *Ibid*, p. 239.

[e] See Gosnell & Pearse (1); Humbert (1), pp. 346–63. Yates (1), pp. 80–9 is the best modern summary of irrigation and water relations in sugarcane.

opened up well before planting, made irrigation at planting and establishment imperative. There must have been some badly drained areas around lakes, which required basin and border bed systems described below for the south, but in most situations north of the ranges, agriculturalists grew sugarcane on well-drained fields elevated above the rivers. They usually planted it on the ridge and furrow system which demanded either furrow irrigation or hand watering from jars or watering cans.

The earliest literary reference to irrigation of sugarcane appeared in the *Nung Sang Chi Yao* of +1273:[a]

> After planting, water (*jao-chiao*[1]) every two or three days if the soil is dry. If there has been a moderate amount of rainfall, water once every ten days. When the sugarcane seedlings attain a height of over two *chhih*[2] [62 cm] water frequently on an extensive scale.

It is uncertain whether the word *jao-chiao*, or watering, referred to flooding the whole field as in wet rice cultivation, or to watering each sett individually. The general principle of irrigation is to supply the plant with the amount of water it can use. During the early stages of growth when the sugarcane plant carries few leaves it needs little water, but when the leaves are fully expanded and the crop closes in, it transpires large quantities. One could speculate that growers hand-watered the cane setts from reservoirs or tanks until the roots became well established deep in the soil, after which they ran water down the cane rows. This passage would then have described a two-stage system, the 'water frequently on an extensive scale' referring to the second operation of flooding down the rows. Whatever the interpretation, this passage clearly warned agriculturalists that irrigation for sugarcane differed from that practised with wet rice cultivation.[b] Wang Hsiang-Chin[3] brought this point home in his *Chhün Fang Phu*[4] of +1621:[c]

> Though frequent irrigation [is necessary], the water should not be permitted to remain in the field for long, but merely made to flow abundantly through [the furrows] to soak [into the soil and] wet [the setts].

Here Wang emphasised the importance of avoiding over-watering. The technique involved running water through the furrows for a brief period of time to moisten the roots of the sugarcane. The *San Nung Chi*[5] of c. +1760 also gave similar instructions:[d]

[a] *NSCY*, ch. 6, p. 14a. Full-scale irrigation was probably not mentioned in the *TSP* because it was unnecessary. In Fig. 33 a patch of 1,500 mm rainfall is shown at Chhêng-Tu[6] just next to Sui-Ning[7], the sugarcane-growing area described in the *TSP*, and this would not have necessitated irrigation. This also applies to Fukien the other large sugar-manufacturing area in the Sung which lies within a high rainfall belt.

[b] For rice irrigation in south China see Vol. 6, pt 2, pp. 107–8.

[c] *Chhün Fang Phu, hêng pu*, ch. 4, p. 13b.

[d] *San Nung Chi*, ch. 17, p. 7a.

[1] 澆漿 [2] 尺 [3] 王象晉 [4] 群芳譜 [5] 三農紀
[6] 成都 [7] 遂寧

When dry [the sugarcane] should be moistened, and if flooded it should be drained (*kan*[1]). Do not allow water to flow over onto the ridges (*wu ling chhi-kou nei chu shui*[2])

Once again the worry was with not over-watering, a justified concern in areas where cultivators were accustomed to heavily irrigate rice. These texts seem to infer that the important difference between sugarcane and wet rice irrigation was that the former required a good drainage system to remove water from the field, while the latter aimed to keep water in the field. The methods described were basically irrigation down the row, it was not until late in the crop cycle that cultivators hilled the soil in the inter-rows up onto the rows, enabling inter-row irrigation. This was unfortunate as inter-row irrigation is more efficient than down the row, because the plants in the row affected the flow of irrigation water; the sugarcane at the point of entry became over-watered, while that on the end of the rows remained under-watered. The advent of the mould-board regime narrated in the *Thien Kung Khai Wu* of +1637, increased the feasibility of inter-row irrigation. This marked a major break-through and has become the major method of the 20th century. Gosnell and Pearse put the method succinctly: 'the cane is irrigated in the rows for some 2–3 months from planting, after which the ridges are split and irrigation continues down the inter-row'.[a] In their experiments they found about 300 per cent increase in flow rate with inter-row irrigation, and a total of five advantages.[b] The mould-board regime also had a big advantage for ratoon irrigation – the furrows could be opened up on each side of the sugarcane rows and irrigated. Alternatively, the entire inter-row could be flooded, as shown in Fig. 49.

Agriculturalists applied the traditional Chinese equipment of noria (*thung chhê*[3]), chain-pump (*lung ku chhê*[4]), reservoirs and tanks for general irrigation treated in Volume 6, part 2, for sugarcane.[c] Members of the Macartney embassy of +1793, and later 19th-century visitors have left accounts of the methods practised on raised areas north and south of the ranges. Sir George Staunton narrated the initial operation of water lifting:[d]

Inundated fields were here succeeded by extensive plantations of sugar cane. To apply the system of irrigation to those plantations, which were on a sandy soil far elevated above the river, it was necessary to raise the water to heights which could not be attained by the methods hitherto mentioned to be practised by the Chinese.

Staunton then commented that the solution was the noria (*thung chhê*), described

[a] Gosnell and Pearse (1), p. 876.

[b] The five advantages of inter-row irrigation given by Gosnell and Pearse (1), pp. 876–7 were: greater distribution efficiency, easier mechanisation, reduced lodging (falling over), improved flexibility and labour requirements.

[c] Vol. 6, pt 2, p. 109.

[d] For a detailed description of the noria see Staunton (1), vol. 3, pp. 335–8.

[1] 乾 [2] 勿令畦溝內注水 [3] 筒車 [4] 龍骨車



Fig. 49. A ratoon field of sugarcane under irrigation in Australia. The soil has been ploughed away from the cane rows with a mould-board plough and water run down the furrows; from King, Mungomery & Hughes (1), opposite p. 144.

in detail the construction of a noria (see Fig. 50), and finally elaborated on the rates:[a]

These wheels [*noria*] are from twenty to forty feet in diameter, according to the height of the bank, and consequent elevation to which the water is raised. Such a wheel is capable of sustaining with ease twenty tubes or spouts, of the length of four feet, and diameter two inches in the clear. The contents of such a tube, would be equal to six-tenths of a gallon, and a periphery of twenty tubes, twelve gallons. A stream of a moderate velocity would be sufficient to turn the wheel at the rate of four revolutions in one minute, by which would be lifted forty-eight gallons in that short period; in one hour, two thousand eight hundred and eighty gallons; and sixty-nine thousand one hundred and twenty gallons, or upwards of three hundred tons of water in a day.

These machines lifted water either directly into the fields or into reservoirs. John Barrow, private secretary to the Earl of Macartney, who accompanied him on the mission, also noted that after initial raising by the noria, agriculturalists sometimes distributed water to the fields via channels with the much-celebrated Chinese chain-pump, the *lung ku chhê* (see Fig. 51):[b]

Every plantation near this part of the river had its wheel and some of them two; and the water raised by them was sometimes conveyed at once into the plots of canes and

[a] *Ibid.*, pp. 337–8.
[b] Barrow (1), pp. 540–1.

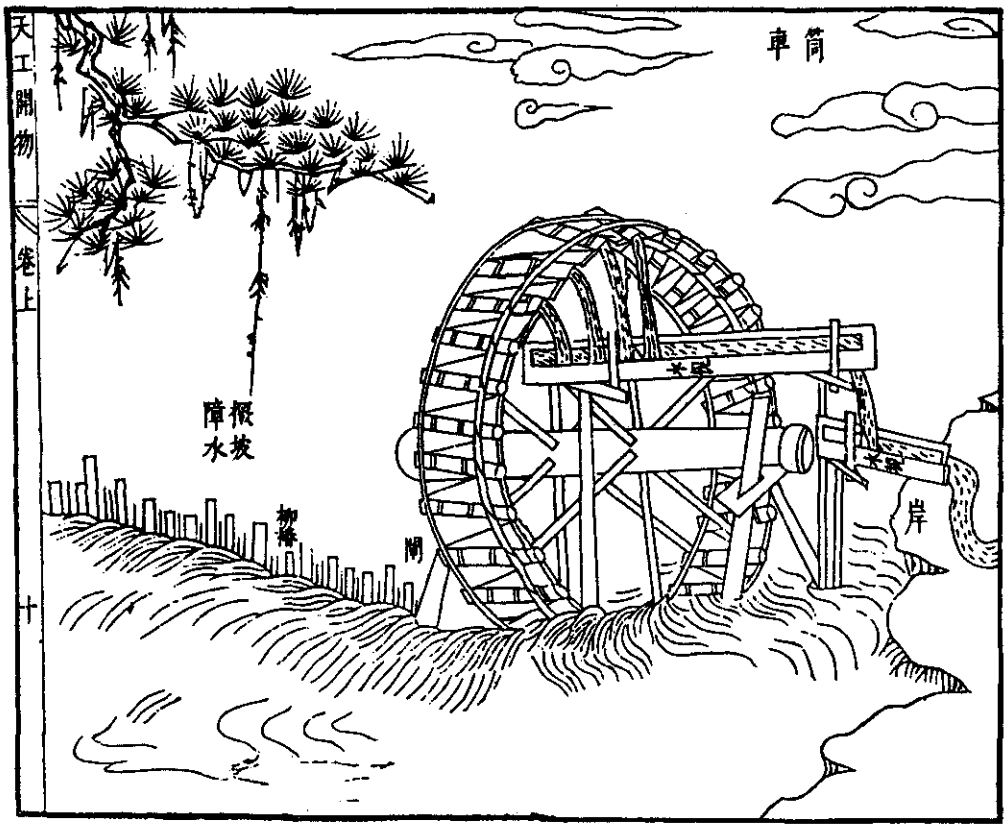


Fig. 50. A giant noria in action as depicted in the 1959 Chung Hua reprint of the original +1637 edition of the *Thien Kung Khai Wu*, ch. 1, pp. 9b–10a. These machines lifted water to 70 feet, powered by the flow of water in the river, and also operated in the sugarcane districts with deeply dissected banks in northern Kuang-Tung and Chiang-Hsi.

sometimes into reservoirs, out of which it was afterwards pumped, as occasion might require, by the chain-pump and carried to those places where it might be wanted along small channels coated with clay.

The mid 19th-century author Henry Charles Sirr related how water stored in tanks could be channelled down the furrows by gravity when needed:[a]

The mode adopted is, conducting water through trenches, from the large reservoirs, which are placed between each row of canes; and at regular intervals, the water is allowed to flow through transverse trenches: these trenches are either opened or closed, as the canes in their respective securities require moisture.

The antiquity of these methods remains unknown, but it is certain that sugarcane could not be grown in these areas without irrigation, and equally certain that this was the only equipment available to lift water. As all the machinery was in operation prior to the Sung, we can conclude that the combinations de-

[a] Sirr (1), p. 334.

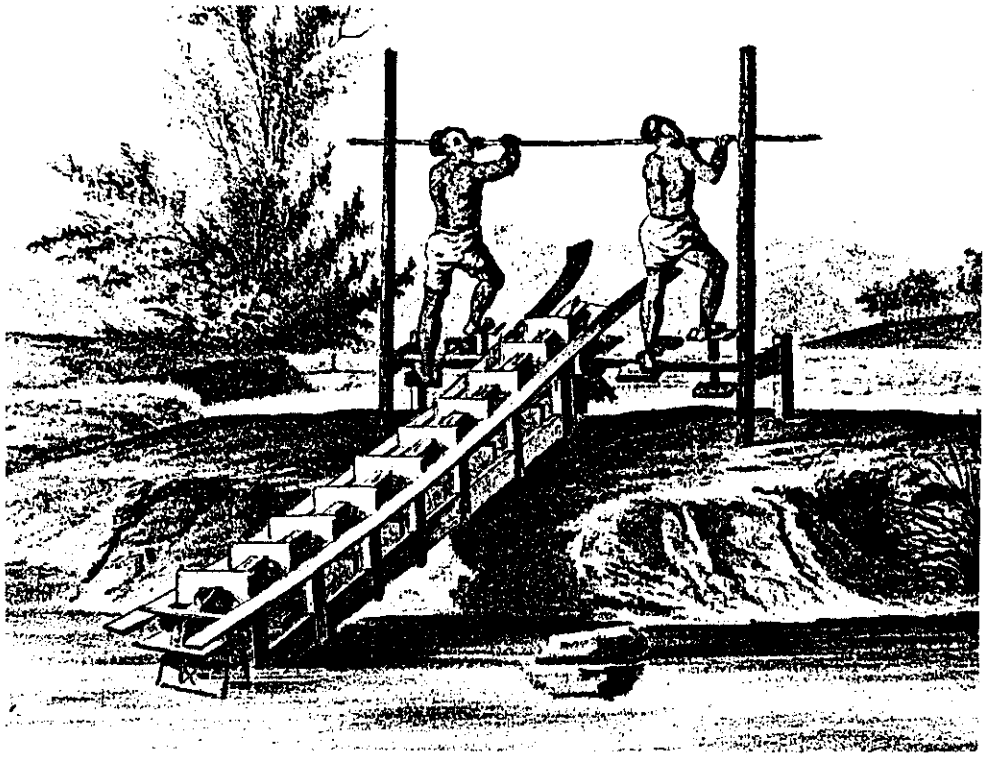


Fig. 51. Raising water by square-pallet chain-pumps (*lung ku chhê*[1]) in 19th-century China in Kuang-Tung. These pumps were employed for short lifts from reservoirs or low streams; West (1), pl. 3.

scribed earlier, dated from the commencement of sugarcane commodity production with irrigation. We also conclude that agriculturalists south of the ranges applied these methods in appropriate situations.

As noted above under Arabic agriculture (see p. 193), neither Chinese texts nor European sources on China mentioned stopping watering to slow down growth and promote sugar accumulation prior to harvesting. This did not present a problem in the north as temperature was a limiting factor, and roots did not function and take in water when day temperatures fell below 19–20°C.[a] It was highly probable that in most areas growers practised irrigation to establish sugarcane before the monsoon season, and only after it in case of severe drought.

South of the ranges

In most areas of Kuang-Tung and Fukien cultivators employed irrigation when available at planting to assist germination, and then as required until the

[a] Yates (1), p. 82.

[1] 龍骨車

monsoon arrived. However, by the +18th century, there were considerable areas on terraced and unterraced hillside that could not be irrigated, and on this land planting had to be delayed until the commencement of the monsoon. During the 20th century, 50–70 per cent of the sugarcane areas of south China lacked irrigation.[a] In the irrigated areas, the problem was compounded by the various types of land utilised for growing sugarcane. Most of the flat land in the south has drainage problems of some sort, and sugarcane was grown under the full range of irrigation techniques which varied with local conditions.

In rice areas cultivators planted sugarcane after paddy rice harvest with judicious flood irrigation.[b] In better-drained situations they grew cane on mounds prepared prior to planting, necessitating some form of irrigation at planting. Mr A. Duncan, surgeon to the British East India Company factory at Canton in the +18th century narrated a typical example. After observing that the Chinese planted on the tops of mounds, and 'occasionally watered [the cane setts] at sunset, till the young shoots rise a cubit high', he wrote: 'The canes are now left to the fertility of the soil till they arrive at maturity, except when it proves such a dry season that watering becomes requisite'.[c]

Blume observed cultivation in the 20th-century Pearl River delta on the tidal coastal lowlands where sugarcane is planted on ridges, and intercropped with soybeans and peanuts in the furrows.[d] The irrigation in these areas is subsurface and controlled by letting limited amounts of water into the fields through the furrows. In the Pearl River delta a considerable portion of the land area is given over to a dyke-pond system in which land is divided into fish ponds, sugarcane fields, paddy rice and mulberry trees in descending order of importance:[e]

> The fish ponds, surrounded by dikes, are used for producing a variety of marketable fish, particularly carp. Water is taken from the ponds to irrigate sugar cane fields. The mud of the bottom of the ponds is used for fertilising the sugar cane and the mulberry trees on the dikes. Whilst the leaves of the mulberry trees serve as food for the silkworms their excrement and the refuse from processing sugar cane is fed to the fish.

Natalis Rondot, a French visitor to Kuang-Tung during the 1840s, related sugarcane cultivation in paddy rice fields:[f]

> Each field is surrounded by dykes of earth used as paths for walking and as a means of maintaining continuation of the feeding channels of stream irrigation. Sugarcane plantations are in the same agricultural condition as the rice fields, the watering by small channels is effected with as much intelligent solicitude as in the vegetable gardens, the water lilies and arrow-head.[g]

[a] Blume (1), p. 239.
[b] Staunton (1), vol. 3, pp. 219–20.
[c] Roxburgh (1), vol. 3, p. 27.
[d] Blume (1), p. 243.
[e] Blume (1), p. 243
[f] Rondot (1), p. 201.
[g] This is the plant *Sagittaria sagittifolia* L., commonly known as *tzhu ku*[1] in Chinese.

[1] 慈菇

In the south starting in the +16th century, sugarcane planting expanded on to land dependent on natural rainfall such as hillsides, where irrigation proved difficult. In such situations normal strategies included planting later, closer to the monsoon, planting from sugarcane ratoon root stocks that were already germinating, and with two rows of plants in each furrow, instead of the normal one. Charles Gustavous Eckberg wrote of the procedure around Kuang-Chou in the mid +18th century.[a]

> The roots of the sugar-cane cut into pieces, (each of which had a shoot or two) were planted more than half a foot deep into the ground; and two feet space was left between every two rows.[b] They planted them both on the highest terraces, and in the lowest places. In *March* and *April* these roots were planted in the low places, and in the rainy season on the hills, which occasioned two different crops. These canes were by no means tender; for they throve in shade and sunshine, wet and dry, heat and cold. When the canes began to grow yellow, they were cut; for when they stood longer, they grew mouldy at the root.

If the monsoon arrived late, or failed, cultivators had to resort to the type of action poetically depicted in the *Kan-Chê Yao*[1] or Sugarcane Ballad by Lu Jo-Thêng[2] of Fukien during the early +17th century:[c]

> Alas, the people of my village live on poor land,
> More than half of their livelihood is in the plantations,
> Extending on for miles, planted because the soil is suitable,
> And sugarcane yields profits equal to those from millet and rice,
> In recent years that demon the drought has wrought cruel disaster,
> Without rain from spring till winter, scorched in the sun,
> They vie to carry jars to water the fields morning and evening,
> Toiling diligently to save the cane as if rescuing their fathers,
> Saving one stalk of cane is worth one *wên*[3],
> Everybody looks pleased and shows a happy face,
> Who would have thought that violent soldiers in packs of hundreds,
> Fond of sweetness but inconsiderate of other people's toil,
> Drawing their swords and cutting it like grass,
> Get even more angry if the owner protests.

This ballad admirably depicted the risks involved in growing sugarcane during the turmoil of the late Ming and early Chhing periods, when cultivators could lose the fruits of their labours at one stroke of the sword. More importantly for us, it highlighted the hazards encountered when sugarcane growing extended

[a] Osbeck (1), p. 296.

[b] I.e. two rows of seed cane pieces were planted in one furrow. There was a two-foot spacing between furrows.

[c] *Tao I Shih*, p. 16. Lu was a native of Quemoy[4] island in Thung-An county[5], Chhüan-Chou[6], a well-known sugar producing district of Fukien, who attained the rank of *chin-shih*[7] in 1640, and later served as an official under the Southern Ming.

[1] 甘蔗謠 [2] 盧若騰 [3] 文 [4] 金門 [5] 同安縣
[6] 泉州(府) [7] 進士

onto marginal land with no irrigation facilities; water had to be hand-carried in earthenware jars to the canefields. Needless to say, this entailed a great deal more labour than that required by cultivators with irrigation facilities.[a]

(vi) *Fertilisation*

Sugarcane plants grown under conditions with balanced nutrition display dark green leaves with vigorous tillering and growth. Deviations from the ideal result in distinctive leaf symptoms, which are exhibited when elements fall below critical threshold levels.[b] Sugarcane is very demanding on the major nutrients nitrogen (N), phosphorus (P) and potassium (K), and about 120 kg N, 75 kg P_2O_5 and 150 kg K_2O are absorbed from the soil to produce 100 tonnes of cane.[c] Therefore high soil fertility or liberal applications of fertiliser are necessary for major elements N and K affect sugar content as well as yield. Over-application of nitrogen or applications late in the crop cycle can induce lower sugar content.[d] The lower sugar content in Kuang-Tung sugarcane from 1977 to 1982 has been attributed in part to over-application of nitrogen.[e] K fertilisation affects sugar content in the opposite way, when a crop is deprived of K, sugar content becomes low; adequate K fertilisation is exceedingly important.[f] Comparatively speaking sugarcane is more tolerant to salinity, acidity and alkalinity than most other crops.[g] On a world-wide basis trace element responses are also usually rare, and only confined to problem soils in various countries.[h] In Volume 6, part 2 it was shown that most Chinese soils under cultivation in south and central China lack NPK, minor elements, and are often acidic.[i] Recent research in Fukien has confirmed responses in sugarcane to NPK and to trace elements Zn, Mo, B, Mn, Fe (in order of importance),[j] and in Kuang-Tung a response has been reported for the trace element rhenium.[k] It is obvious that the sugarcane lands of China are highly deficient in major and minor trace elements, and they are often acidic, and saline in some of the delta areas.

[a] The *THSCL* of +1736, p. 56 reported that a great amount of labour was expended on irrigating sugarcane fields with buckets slung on ropes and operated by two men (*hu shui Kuan Kai*[l]) when rains failed in south Taiwan.

[b] See Martin & Evans (1) for numerous coloured illustrations of symptoms of major and minor element deficiencies of sugarcane.

[c] Blume (1), p. 66.

[d] Humbert (1), p. 266.

[e] Blume (1), p. 240.

[f] See Humbert (1), p. 267 for a report on world-wide data, potassium is involved in the synthesis and translocation of proteins. Chang Chin-Yü (*1*) has reported on the beneficial effects of K on juice quality in Fukien.

[g] Blackburn (1), pp. 44 and 47.

[h] *Ibid.*, p. 52.

[i] Vol. 6, pt 2, pp. 25–6.

[j] Li Shuang-Lin (*1*); see Kuo, Cheng, Yang and Chang (*1*) for additional supportive experiments on minor elements, and Lin Hui (*1*) for a study of the effect of boron (B) in particular.

[k] Wang, Tai and Li (*1*).

[l] 戽水灌溉

North of the ranges

The Chinese, aware at least from the +12th century that sugarcane taxed soil fertility, recommended the application of fertiliser to make up the deficiencies. The *Thang Shuang Phu* of c. +1154 was the first text to document the application of fertilisers at planting and during growth.[a]

> Lay the [cane] in rows with intervals between [the setts] (*hang pu hsiang chhan*[1]). Cover the setts thinly with ashes and add not more than two *tshun*[2] [6 cm] of soil. On two occasions, Tomb Sweeping Day (*chhing ming*[3]) and the Dragon Boat Festival (*tuan wu*[4]) respectively, thinly apply ashes finely mixed with pig and cow manure ... Half way through the sixth lunar month apply manure once again.

This text prescribed fertilisation at four different stages of plant growth; first on planting[b] and then a further three applications about two months apart. This was an ideal regime, as it made fertiliser available for germination, early growth and boom growth periods. The mixtures applied would have provided a balanced nutrition; the application of ashes as a source of K is noteworthy. Modern practice is to apply a portion of the fertiliser at planting to furnish the young plants with a large amount of the required fertiliser from the start. A second and possibly third application is administered prior to the boom growth period, and timed a few weeks beforehand, so that the plant has a chance to absorb the fertiliser before the monsoon, thus minimising loss from leaching.[c] On the world scale, modern research has not been able to demonstrate any advantage from splitting fertiliser applications, but most cultivators do so from a common-sense point of view. The only major trap with fertilisation is that if nitrogen fertilisation (night soil etc.) is applied too late and too heavily, it will lower juice quality, because the cane will continue to grow and not ripen. The fertilisation regime prescribed in the *Thang Shuang Phu* approximated to the ideal apart from the late application, which could have affected juice quality.[d] Late applications of nitrogen are more critical in the northern zone because premature cold weather can stop growth before the nitrogen supply is exhausted.

Next let us look at the main methods of fertilisation practised in succeeding centuries. First, the attention given to regular fertilisation was not peculiar to sugarcane cultivation, but a general trait of Chinese agriculture. Later texts mentioned the application of manure, both human and animal. For example the *Chhün Fang Phu* of +1621 recommended 'taking soil and piling it up on the

[a] *TSP*, pp. 3a–3b; Liu & Liu (1), p. 14.

[b] Alternatively, fertiliser may be applied to the setts in the transplant seed bed. The *TKKW*, p. 163, recorded fertilisation in the germination beds: 'When the node grows one or two *tshun* [3–6 cm] high, water it regularly with clear liquid manure (*chhing fen shui*[5]).'

[c] For fertilisation on a world scale see Blackburn (1), pp. 52–63 and Humbert (1), pp. 133–301.

[d] It is generally recommended that the last application of nitrogen be five months before harvest, see Blackburn (1), p. 55.

[1] 行布相儭 [2] 寸 [3] 清明 [4] 端午 [5] 清粪水

roots, and adding manure in the seventh lunar month'.[a] However, from the +17th century onwards the types of fertilisers applied came to be more diversified. The *Chih Fu Chhüan Shu*[1] of +1620 advised 'the use of animal and human manure (*fei fên*[2]) or the residue cake of sesamum seeds (*ma ping*[3]) to pile onto the shoots when they come out in the third lunar month [April].'[b] Apart from human and animal manure, the *Thien Kung Khai Wu* of +1637 also recorded the application of cake residue left over from extracting oil from the seeds of sesame (*hu ma*[4]) [*Sesamum indicum* L.] and rape-turnip (*yün thai*[5]) [*Brassica campestris* L. R473] to sugarcane in the field:[c]

> The amount of supernatant manure to be applied (*chiao fen*[6]) depends on the fertility of the soil. When the [cane shoots] reach a height of one or two *chhih* [32–64 cm] mix with the [liquid] in which the residue cake (*khu*[7]) of sesamum and rape-turnip seeds has been soaked with water and pour (*kuan*[8]) [it onto the cane plants]. Pour the fertiliser in the [cane] rows.

Sesame and rape-turnip cakes were soaked in water and the resultant supernatant fertiliser was poured on to the beds. In dry weather or in dry areas, it was advantageous to mix the fertiliser with water and apply it, otherwise the plant could not adsorb it due to lack of moisture. The word for applying fertiliser, *kuan*[8], translated here as 'pour', could either refer to running the water down the furrows or to hand watering. Since field irrigation would require large amounts of fertiliser, I suggest that the text referred to hand watering. The *San Nung Chi* of c. +1760 also mentioned the application of similar fertilisers: 'When [the cane plants] reach over one *chhih* [317 mm] in height, pile ashes, manure and sesamum cake under the roots ...'[d] This account could be interpreted to indicate that the fertiliser was applied to the cane rows after they have been opened up by ploughing away with a mould-board plough during inter-row cultivation, and then covered on the next pass which ploughed soil back on to the cane rows. This was practised in fertilisation regimes in some other countries, which have continued into the 20th century.

South of the ranges

We do not have any early evidence for fertilisation south of the ranges. In the +18th century, A. Duncan, the English factory medico at Canton, wrote, 'a compost of human manure and water is now thrown over the beds' before

[a] *Chhün Fang Phu, hêng pu*, ch. 4, p. 13b.

[b] *Chih Fu Chhüan Shu*, of +1620, ch. 5/chê. The same line occurred with slightly different wording in the *Chih Fu Chhuan Shu*, of +1678, ch. 1, p. 26a. In this latter work, rather curiously, the words 'animal and human manure' have been replaced by 'dog manure (*chhüan fên*[9]); though one naturally expects that all types of manure, not just the canine variety, were applied.

[c] *TKKW*, p. 164.

[d] *San Nung Chi*, ch. 17, p. 7a.

[1] 致富全書 [2] 肥糞 [3] 麻餅 [4] 胡麻 [5] 芸薹
[6] 澆糞 [7] 枯 [8] 灌 [9] 犬糞

planting to enrich the soil'[a]. On the basis of this slender evidence, we assume that the traditional Chinese fertiliser, night soil, served as the major fertiliser. Though the peanut or groundnut (*Arachis hypogaea* L.)[b] arrived in south China from South America as early as the +16th century, the husks and refuse left from extracting peanut oil were not mentioned as a fertiliser for sugarcane until the +18th century, when agriculturalists in the Pearl River delta region applied them along with the refuse of other oleaginous seeds. For this region they are not reported as being made into a supernatant fertiliser, but 'well beaten into a kind of powder, and put around the roots of the plants in small quantities and afterwards covered over with earth.'[c] Soybean cake (*tou ping*[1]) appeared as a fertiliser for wet rice in the *Pien Min Thu Tsuan*[2] of +1502, and for the cotton plant in the *Nung Chêng Chhüan Shu*[3] of the early +17th century, but eluded mention for application to sugarcane until the 19th century when imported into Fukien and Kuang-Tung in large quantities.[d] A husbandman's aphorism from Chiang-Hsi attested to its efficacy: 'If you want sugarcane to grow well, do not skimp on soybean cake (*tou-ping*)'.[e]

After the +16th century, increasing pressure for intensification in southern Chinese agriculture led to the application of the refuse from pressing oleaginous seeds as a fertiliser, to increase yields. All sugarcane crops need large amounts of nitrogen fertilisers, and responses are usually obtained even on the best land. Phosphorus and potassium, the other two major nutrients, vary from soil to soil.[f] Bean cake contains appreciable amounts of nitrogen,[g] and as such makes an excellent fertiliser for all cane land and is extensively applied in modern India. In addition, it probably acts as a soil conditioner and helps keep the soil friable. It is therefore with good reason that at the height of the Chinese sugar industry from the 1870s to the 1890s, bean cake was imported into south China from Manchuria in great quantities.

(vii) *Growth and harvesting*

Sugarcane is harvested during winter. In China it can be anything from nine to fifteen months old at harvest, depending on the time of planting and the onset

[a] Roxburgh (1), vol. 3, p. 27.
[b] For the peanut see Vol. 6, pt 2, pp. 516–18.
[c] Roxburgh (1), vol. 3, p. 27.
[d] *Pien Min Thu Tsuan*, ch. 1, p. 3b; ch. 2, p. 2a.; *Nung Chêng Chhüan Shu*, p. 966; and Adachi (1), p. 48 for application to sugarcane.
[e] Chiang-Hsi Nung-Yen Pien-Chi-Tsu (1), p. 122.
[f] Vol. 6, pt 2, p. 28 Table 1, shows that southern Chinese soils are generally short of NPK. This probably does not necessarily apply for PK on deep fertile river-bank land on which much sugarcane was grown during the Ming and Chhing periods.
[g] According to Deerr (2), p. 94, bean cake contains 4–8 per cent N; the application would have to be fairly liberal to be effective.

[1] 豆餅 [2] 便民圖纂 [3] 農政全書

of cold weather. The sugar content *potential* of a crop is governed by the number of growth days prior to the ripening process,[a] which normally commences with the slowing down of growth in late autumn. Ideally harvest should be delayed until maximum sugar content is realised when the cane becomes fully ripened and mature.[b] As sugarcane enters the ripening period, fertilisation, and in particular nitrogen, should be depleted. The ripening process is initiated by climatic conditions putting mild stress on the plant, so that active growth gradually ceases, but as photosynthesis continues, there is an increase in sucrose per cent cane. As well as sucrose accumulation, glucose and fructose convert to sucrose and the purity of the juice rises; this is most important for sugar manufacture as glucose and fructose slow down the rate of crystallisation of sucrose.[c] The two prominent ripening factors are mild moisture stress and temperatures falling below 20°C, but not near freezing.[d] Southern China has a potentially good climate for sugar storage and ripening of sugarcane, as there is a long growing period and the winter harvesting season is dry and cool. Blume rated Kuang-Tung as seventh out of thirty-nine entries on a world scale. North of the ranges Ssu-Chhuan came thirty-second on the same rating, and this was a reflection of the shortened growth period and inadequate ripening due to the onset of freezing weather.[e] South of the ranges temperature and soil moisture interact in ripening,[f] while north of the ranges temperature is the governing factor because roots become inactive at about 20°C and will not take up water.

How did growers harvest the stalks? One is apt to think that the rise of commodity sugarcane agriculture would depend on having good quality steel knives to cut the stalks. However, we discovered that agriculturalists in +18th-century Spain harvested sugarcane by breaking stalks manually:[g] 'They [the stalks] are gathered, when perfectly ripe, by bending them down to the ground, which breaks them off near the root; or they may be broken off by taking them near the root, and drawing them towards you.' As stated earlier (see p. 143), the *Nan Fang Tshao Mu Chuang* of +304 remarked of sugarcane: 'when broken and eaten it is very sweet'. Also the first illustration of a sugarcane stalk in China in the

[a] A long, warm growing season with adequate moisture and correct fertilisations is optimum, see Blume (1), p. 51.

[b] This is commonly defined as when the stalk loses its normal sugar content grading down the stalk, and has the same sugar concentration in the top, middle and bottom. See Blume (1), pp. 38 and 70. There has been some scientific controversy about ripening, because the increase of sugar concentration during ripening is due to three factors. First, genuine sucrose accumulation due to photosynthesis; second, the conversion of reducing sugars, glucose and fructose into sucrose; and third, loss of water due to water stress. The third factor does not produce any extra sugar per unit area of ground, see Bull and Glasziou (1), pp. 63–4. See Alexander, A.G. (1), pp. 397–439 for a comprehensive review of ripening at the field, cellular and biochemical levels.

[c] See Blackburn (1), pp. 248–9 for purity rise during ripening: Meade (1), p. 221 for a discussion of the effects of impurities on boiling rates and crystal yields.

[d] Bull and Glasziou (1), p. 63.

[e] Blume (1), p. 81, table 18. The mean annual temperature in Ssu-Chhuan is only '17 to 19°C which is the lowest figure encountered anywhere in the world's regions of sugarcane agriculture', see Blume (1), p. 239.

[f] Research in modern Fukien has confirmed the major effects of sunlight, temperature and rainfall in ripening, see Chou I-Fei (*1*). Chou adds day–night temperature differential as a fourth factor.

[g] Valcarcel cited in Coulter (1), p. 255.

Cheng Lei Pei-Yung Pên Tshao[1] of +1249 showed a section of a stalk that has obviously been broken from the stool (see Fig. 28). These two isolated remarks indicate that this may have been a method of harvesting practised in China from early times up to the Sung. The *Thang Shuang Pu* of c. +1154 mentioned cane knives for chopping harvested sugarcane into shorter pieces on benches.[a] Otherwise the actual method of harvesting has eluded the written record.

With sugarcane sold as fruit the Chinese selectively harvested large stalks from the cane standing in the fields. Ernest Henry Wilson, a naturalist who spent eleven years in China from 1899 observed the following: 'The canes are cut as they mature and sold as required; the canes that remain at the end of the season are taken up by the roots in November, cleaned and stored in earthen burrows until required for sale.'[b] Here agriculturalists practised the orchard principle of picking the large ripe fruit first, and leaving the smaller fruit to grow and ripen. In the southern zone sugarcane could be left standing in the field over the winter, while in the northern zone they had to be harvested and stored underground as soon as the first frosts approached.

Transportation of harvested cane presented problems common to both north and south of the ranges. In both zones, ideally, cultivators grew sugarcane alongside the mill to facilitate transportation. This was probably the most common case in the northern zone because most growers had to have their own milling equipment to crush cane rapidly before the onset of the frost. After the appearance of vertical double-roller mills from the late +16th century, agriculturalists in both zones transported sugarcane in sampans or carts to central positions, where they erected temporary mills. This arrangement may derive from earlier times when the *frangourinier* (*khun nien*[2]) featured as the main crushing equipment.[c] Chréton Louis Joseph de Guignes has left an account of a late +18th-century cart in Kuang-Tung:[d]

> The carts used for carrying cane are heavy; the wheels are solid and narrow; the shafts are 16 feet long, 4.5 feet at the rear and three at front. They are joined by traverses placed at intervals. A piece of wood bent back, which begins at the end of the shafts, is placed on the neck of the buffalo to enable him to pull this heavy machine.

Growers probably used such carts to convey sugarcane to portable mills erected in cane fields as well as to fixed mills.

North of the ranges

The *Thang Shuang Phu* stated that sugarcane was harvested during the tenth lunar month (about November),[e] which meant that it must have been growing

[a] *TSP*, p. 4a.
[b] Wilson, E.H. (1), vol. 2, p. 85.
[c] See section (e) Cane sugar manufacture.
[d] de Guignes (1), vol. 1, p. 265.
[e] *TSP*, p. 3b. The *Chih Fu Chhüan Shu* of +1620, ch. 5/*ché* recorded that sugarcane is harvested early in the tenth lunar month as did the *Chih Fu Chhüan Shu* of +1678, ch. 1, p. 25b.

[1] 證類備用本草 [2] 輥輾

for only eight or nine months at the most. The *Nung Sang Chi Yao* of +1273 also remarked:[a]

[Sugarcane] bears neither flowers nor fruit. In the ninth lunar month after the frosts [come, cut a cane stalk] and taste it. If the flavour is 'sweet and sour' (*suan thien*[1]) the cane is mature, but if it is bitter it is still unripe. Cut the mature sugarcane near the root.

Since sugarcane 'bears neither flowers nor fruit' at these latitudes the only way to determine whether it is ripe or not at this time, is to taste it. As mentioned earlier, frost was a major limiting factor in sugarcane-growing areas in higher latitudes. Sugarcane loses the ability to increase sugar content when frosted, so it must be harvested as rapidly as possible. Nevertheless, colder weather is a double-edged sword in the sense that though low temperatures ruin sugarcane, about a month at 20°C will induce a higher sugar content in sugarcane. The passage from the *Nung Sang Chi Yao* quoted here seems to indicate an awareness of the changes in the sugar content that arise after a drop in temperature. The first Chinese text to indicate an appreciation of the relationship between a fall in temperature and an increase in sugar content was a gazetteer for a prefecture in Chiang-Hsi province, the *Fu-Chou Fu Chih*[2] of +1554, which stated: 'The flavour of sugarcane only becomes excellent [just] after *shuang chiang*[3] [roughly October 24 when the frosts begin].'[b]

The first Chinese text to reveal detailed knowledge of the relationship between frost and harvesting was the *Thien Kung Khai Wu* of +1637:[c]

It is the nature of sugarcane (*chê hsing*[4])[d] [for the juice] to gradually turn red-black in autumn; change from red to brown and finally white after the winter solstice [December 22]. In the frost-free land of the provinces south of the Five Ranges sugarcane may be left [in the fields] uncut for extracting [the juice for making into] sugar candy (*thang shuang*[5]). North of Shao-Chou[6] and Nan-Hsiung[7] [in northern Kuang-Tung] where frosts attack in the tenth lunar month [approximately November], the sugar content of the cane (*chê chih*[8]) is immediately destroyed when frosts fall, and as the stalks will not last long enough [for the juice] to turn white in colour they are quickly cut down

[a] *NSCY*, ch. 6, p. 14a.

[b] +1554 *Fu-Chou FC*, ch. 5, *Ti-li chih*, p. 5a. The term *shuang chiang* literally means frost fall, and is a calendrical term indicating the period when frosts begin. Also quoted in Tai (*1*), p. 79.

[c] *TKKW*, pp. 165–6.

[d] The modern commentary to the *TKKW*, p. 165, interpreted the two words *chê hsing* as referring to the appearance of the rinds, but since it is not certain whether the character *hsing*[1] can mean cuticle we give the common rendering of *hsing*[9] as nature. Furthermore, since the juice of sugarcane does change from dark brown to white-yellow as the crushing season progresses into winter the colour change undoubtedly referred to that of the juice and not of the rind. It should be noted that remarks about cane turning yellow in Chinese texts could refer to the leaves, the colour changes of which are more striking than those of the stalk. One of the normal features of ripening is that the cane leaves turn yellow as the amount of nitrogen in the stalk depletes. Charles Gustavius Eckeberg wrote: 'When the canes began to grow yellow, they were cut; for when they stood longer, they grew mouldy at the root. They grow from eight to twelve feet high', quoted in Osbeck (1), pp. 296–7. Eckeberg's remark referred to the leaves as much as the stalk.

[1] 酸甜 [2] 撫州府志 [3] 霜降 [4] 蔗性 [5] 糖霜
[6] 韶州 [7] 南雄 [8] 蔗質 [9] 性

for extracting [the juice for making into] brown sugar (*hung thang*[1]). In order to make brown sugar, the sugarcane must be harvested during the ten day period [before the first frost]. Before this ten day [period] the juice will not have matured sufficiently and after this ten day period there is a danger that a frost attack may completely ruin the efforts [expended in cane cultivation] up to the present. For this reason households which grow ten *mou*[2] [61.4 ares] of sugarcane [need] to construct a crushing mill and boiling pans in order to meet urgent needs. In frost-free southern Kuang-Tung, people can delay or bring forward the [time of harvest] as they please.

Sung Ying-Hsing[3] the author of this passage, distinguished between the two sugarcane-growing zones that we explained earlier: the frost-stricken areas north of the five ranges which act as a divide between the Yangtse and Pearl River delta areas, and the frost-free zone of Kuang-Tung and Kuang-Hsi which lies south of these ranges. The major difference between harvesting practices in these two zones was dictated by the length of the growing period; in frost zones the growing period of sugarcane was limited to about nine months as the cold weather also delayed early planting, whereas in the frost-free sub-tropical zone sugarcane may have stood in the field for one and a half years, providing economic conditions were favourable.

This climatic limitation meant that cultivators in the frost zones had to have their own crushing mills and boiling pans 'in order to meet urgent needs'; it was imperative to process cane speedily after sudden frosts or cold changes, which could ruin an entire crop at one stroke. In fact as Sung Ying-Hsing remarked, cultivators in the frost zone tried to lengthen the growing period as far into the cold weather as possible, because they presumably realised that moderately cold temperatures raised the sugar content. They also may have lengthened the growing season as long as possible to obtain more sugarcane. Such actions were obviously a gamble for misjudgement of harvesting time could easily lead to low sugar yields or even crop failure. In addition, the *Thien Kung Khai Wu* explained the suitability of sugarcane for making into white and brown sugar in terms of the length of the growing period; the longer the growing time, the higher the sugar content and purity, and the more suitable sugarcane became for making into white sugar. Chinese agriculturalists clearly recognised that frost, which reduced the sugar content, limited the northward expansion of sugarcane cultivation.

South of the ranges

In the sub-tropical, frost-free zone, the absence of frosts freed individual cultivators from the need for owning their own sugar mills, because the warm winters allowed them to alter harvesting time to fit in with the mill's crushing schedule. In fact, after the spread of the portable double-roller vertical sugar mill during the +17th century we find itinerant sugar millers moving around

[1] 紅糖 [2] 畝 [3] 宋應星

the cane fields crushing cane for a fee.[a] The need for sugarcane growers in the northern zone to have their own crushing mills made them less efficient economically than their counterparts in the southern zone. This meant that growers in the south did not have to capitalise as much as in the northern zone, and this made their operations more competitive because they could share crushing and boiling equipment among themselves[b] or hire itinerant sugar makers to do the work. This was a major factor determining the concentration of sugarcane cultivation and sugar making in the southern zone.

(viii) *Ratooning*

When the sugarcane plant is cut to the ground at harvest the old root system dies. The root primordia and the buds on the stem section left underneath the soil, germinate and produce a new crop. This is called ratooning, a term deriving from the Spanish *retoño*. The crop should be cut off level to the ground to ensure that the shoots do in fact arise from below ground, because due to top dominance any above-ground buds will strike first, leading to lower yields.[c] Yields of cane and sugar per hectare decline with progressive ratooning and in most countries, ratooning becomes uneconomic after two or three ratoons. This has been put down to increasing difficulty in maintaining an adequate root system due to progressive soil compaction, but there are probably additional factors.[d] Ratoon crops, nevertheless, have advantages: they lower costs because seed cane, amounting to two to four tons per acre, is not required; labour requirements are lower, and sugar content per cent cane is usually slightly higher.

Yet, ratooning can be disadvantageous for agriculturalists as sugarcane cannot be grown in a yearly multi-crop cycle. In the Mediterranean, Europe and the West Indies they pushed ratooning to its limit, and the crop soon became grown under a monocultural system. Ratooning was not generally practised much in China north of the ranges, where yearly crop rotations remained the norm. South of the ranges with the rise of the commercialisation of agriculture in the +16th century, sugarcane turned into a major crop grown under a two and three ratoon system. Leaving aside social and economic structural differences, I believe that the strategies adopted by the Chinese peasant in adjusting to the growth of the cash economy prevented the change-over to a monoculture

[a] For itinerant sugar millers see (*b*), above. Before the advent of the two roller vertical mill, the southern Chinese had developed a portable sugar mill, based on the rolling mill, see below.

[b] For the history of the collective ownership of sugar mills in south Taiwan during the +18th and 19th centuries, see Christian Daniels (*2*).

[c] Blume (1), p. 75; Humbert (1), p. 127. However, under certain conditions, such as bad drainage, the bottom eyes are killed by stagnant water, while the upper ones remain sound and will germinate, see Stubbs (*2*), p. 157.

[d] Blackburn (1), p. 158; Barnes ((1), p. 230), gave insects and diseases in the roots and the ratoon stunting disease *Clavibacter xyli* sub sp *xyli*., as additional factors.

system as in the West Indies. The Chinese cultivator of sugarcane insisted on safe-guarding himself against the fluctuations of the sugar market by (1) producing a certain amount of subsistence food himself, and (2) growing or maintaining a situation where he could plant other crops to diversify the risks involved with a single crop. Thus from its inception the commercialisation of agriculture in China signalled diversification of crops, and sugarcane had to be grown in rotation or inter-cropping cycles with subsistence and other crops. This made it very difficult for any crop to gain a position of absolute dominance.

North of the ranges

In the passage cited from the *Thang Shuang Phu* under the crop rotation heading below, we shall see that the author, Wang Cho, advised Ssu-Chhuanese cane growers during the mid +12th century to rotate their crops every year, which was another way of saying that they should not grow any ratoon crops. But, 'people with surplus land, at most change [from sugarcane] to grow [another] crop every three years', which implied a plant crop followed by one ratoon in the case of surplus land. This indicated that there was no resistance to ratooning *per se*, it was simply a question of crop rotation. This may not be absolutely correct as for some areas during the 1930s growers uprooted sugarcane after harvesting each year and planted with new setts again, indicating no confidence in the ratooning process.[a] The *San Nung Chi* of the +18th century stated: 'red cane [*Saccharum officinarum*] is planted once a year and white cane [*Saccharum sinense*] is planted once in two years',[b] indicating that agriculturalists adopted ratooning with clones cultivated for sugar making, but not with those for chewing. The practice of ratooning obviously varied with time and place, and its choice was probably determined more by management rather than technological considerations. The *Thien Kung Khai Wu* recommended piling soil on the cane in October to protect the roots left over after harvesting against damage from frost and snow,[c] which was of course sound advice for ratooning; the soil cover prevented the underground buds from being killed. This demonstrated that some ratooning was indeed practised, and as noted earlier adequate ratoon cultivation became possible with the advent of the mould-board plough cultivation recorded in the *Thien Kung Khai Wu*. The first operation was to run the mould board up the side of each row and plough away from cane stool into the inter-row,[d] after which the regular methods prescribed for plant cane could be followed.

[a] Kanda (1), p. 521. Alternatively, the stands of sugarcane may have been so poor due to diseases, such as pineapple disease, that growers had to replant each year.

[b] *San Nung Chi*, ch. 17, p. 7a. It is also recorded here that miscanthus cane was white in colour.

[c] *TKKW*, p. 164. Soil was also piled onto the roots to prevent lodging.

[d] See Humbert (1), p. 75, fig. 73, for a photograph taken in modern Taiwan showing an ox-drawn mould-board plough ploughing away from the row; American agronomists call this operation off-barring.

South of the ranges

Sources on the southern zone neglected the topic of ratooning, and most references, if any, were brief.[a] Nevertheless, the shorter, warmer winter in the south must have given ratoon crops a potentially longer growing period than in the northern zone, because they would germinate as soon as the weather could support growth. Therefore we would expect ratooning to be more widespread in the southern zone. In addition, since the spread of the cash economy from the +16th century gave growers a big incentive to increase efficiency, I hypothesise a greater incidence of ratooning and intercropping. There is also evidence that ratooning differed with clones in this zone as well. Duncan, writing of Kuang-Tung in the late +18th century, said that sugarcane grown for making sugar was planted once every three years, and would therefore include two ratoon crops, while that for chewing was freshly planted each year.[b]

Next let us look at one of the effects ratooning exercised on harvesting patterns. The *Tung Ning Chêng Shih Chi*[1] (Collected Political Affairs of Tung-Ning), a source on sugar production in south Taiwan during the Chêng family occupation period, which lasted from +1661 to +1683, stated:[c]

> Sugarcane seedlings are planted in the fifth and sixth lunar months. First-year cane is disliked for its greenness and third-year cane loathed for its oldness, it is second-year cane that is the best. First-year cane matures in the first lunar month of the following year, while second-year canes mature in the twelfth lunar month of the same year, and third-year canes mature in the eleventh lunar month. Therefore the time for crushing and boiling [*hsia chu*[2]] depends on the respective year of the sugarcane. If cut early there is insufficient juice and little sugar. Generally speaking [harvesting and crushing] work begins somewhere between the twelfth and first lunar months and finishes in early summer.

In this three-year cycle, growers planted sugarcane in the first year and ratooned it for the following two years. They planted first-year cane in June or July, and harvested it about late January or early February of the next year, cut second-year cane in January of the following year and third-year cane in December of the same year. The last section of the passage is interesting for it showed that in the sub-tropical climate of south Taiwan, and of course Fukien and Kuang-Tung as well, ratooning extended the crushing season for longer than was possible in frost-stricken areas, because sugarcane would be ripening at different times depending on whether it was first-, second- or third-year cane. Such spacing of maturing time created a situation in which all the sugarcane

[a] The *KTHY*, p. 689 described what appears to be ratooning: 'Pile earth over the old roots.'

[b] Roxburgh (1), vol. 3, p. 27.

[c] Quoted in *THSCL*, p. 56. I have not come across a classical Chinese term for ratooned cane. The modern Chinese term for ratoons is *su ken chê*[3].

[1] 東甯政事集 [2] 硤煮 [3] 宿根蔗

did not have to be harvested and crushed at once, and thereby allowed milling to take place over a period of up to three months or more. Since this system staggered the harvest time, it gave itinerant sugar makers ample time to travel around the sugar districts of Taiwan and Kuang-Tung, probably helping to encourage the adoption of portable double-roller sugar mills which saved more labour than the previous crushing apparatus.

(ix) *Crop rotation*

Several influential, modern, sugarcane agronomists have abandoned crop rotation and fallowing, as well as organic fertilisers and trash conservation, as strategies for maintenance of soil fertility.[a] They believe that adequate attention to mineral fertilisation will increase yields and maintain organic matter due to the large amounts of roots and stubble produced by each crop. The more conventional view of rotation with fallows, green manure crops and fertilisation with animal manure has some agronomic support,[b] but has virtually ceased in most countries. In China during the 1980s artificial fertilisers formed a large proportion of applications.[c]

North of the ranges

Crop rotation was a well-known feature of Chinese agriculture. The earliest systematic account of it appeared in the +6th-century *Chhi Min Yao Shu*,[d] but it is not until the *Thang Shuang Phu* of c. +1154 that we find an explicit account of crop rotation with sugarcane, although growers undoubtedly practised it much earlier. This text noted the necessity of rotating the cultivation of sugarcane with grain crops.[e]

> Sugarcane is most dependent on the fertility of the soil, and cannot be mixed with other crops. So a cane field this year will be changed to grow [one] of the five grains next year in order to rest the soil. Cultivators with surplus land, at most, change [from sugarcane] to grow [another] crop every three years.

This passage shows that at least from the +12th century the Chinese fully understood that sugarcane cultivation depleted the soil of its nutrients. It narrated two rotation cycles: first, one where agriculturalists grew sugarcane on the same piece of land for one year, followed by a grain crop in the second year, and then sugarcane again in the third year; second, another where cultivators with surplus land grew sugarcane for two consecutive years (plant plus one ratoon crop) on the same plot of land, after which they changed to a different

[a] See review in Blackburn (1), pp. 167–70.
[b] Barnes (1), p. 112.
[c] Australian Sugar Mission to China (1), pp. 8–9.
[d] For crop rotations in China see Vol. 6, pt 2, pp. 429–33.
[e] *TSP*, p. 3b; Liu & Liu (1), p. 14.

crop. In analysing why ratooning failed to enjoy popularity north of the ranges, I see two factors. First, heavy frosts would lead to the death of some stools and patchy stands, the damage depending on the severity of the frost or snow. Second, agriculturalists north of the ranges had a number of basic crops, such as wheat, that could be grown with advantage in a mixed cropping cycle.

South of the ranges

In the climate south of the ranges conditions proved favourable for ratooning, and did not cause premature rotation, permitting the cultivation of two or three ratoons. Cycles for +17th- and +18th-century Taiwan included one in which agriculturalists cultivated sugarcane by ratooning for three consecutive years, after which they planted sweet potatoes for two consecutive years, and sugarcane again in the sixth year.[a] This demonstrates how intensive sugarcane cultivation had become by the +18th century. The large expansion in population during and after the Ming contributed to a gradual increase in intensive agriculture.

Apart from sweet potatoes, peanuts and legumes, agriculturalists sometimes rotated sugarcane with other crops as well. The *Kuang-Tung Hsin Yü* of +1700 recorded a rotation cycle between sugarcane and bananas in the western districts of Tseng-Chheng[1], a county near Kuang-Chou in the Pearl River delta; bananas were planted for three to four years followed by two years of sugarcane, and then bananas again:[b]

Many people cultivate bananas on the islets in rivers in the west of Tseng-Chheng [county]. [They] grow [them] for three or four years and then uproot (*chin-fa*[2]) them to plant white sugarcane (*pai-chê*[3]). White sugarcane can be grown on land on which bananas have been cultivated, [and if done so] it will become increasingly flourishing and sweet. [After] growing white sugarcane for two years, revert to cultivating bananas again [on the same piece of land]. Sweet tooth bananas (*hsiang-ya-chiao*[4]),[c] citrus (*mi-chü*[5]), taro (*yü*[6]),[d] yams (*yü*[7]) and other crops are planted between the banana trees (*chiao*[8]), and they all obtain fragrance and goodness. Bananas and sugarcane are grown in rotation (*hsiang tai êrh shêng*[9]), and as a consequence of the aroma and flavour mixing in together they are superior to those produced elsewhere.

White sugarcane was *Saccharum officinarum*, and probably cultivated for sale as a chewing cane in local urban areas.

[a] The *Tung Ning Chêng Shih Chi* described the rotation cycle on Taiwan, and a translation of the relevant passage has already been given under the Ratooning heading. Also see Daniels (*2*), pp. 98–101. For 19th-century south Taiwan Myers ((*1*), p16) reported three-year rotations. Hara ((*1*), p. 12) and Ōkawa ((*1*), p. 40) differed in writing that cultivators only grew sugarcane for one year or two years on the same piece of land.

[b] *KTHY*, p. 688. Tai (*1*), pp. 77–8.

[c] Probably a variety of *Musa sapientum* L. R 652.

[d] Here we follow the text of the +1700 original, ch. 27, p. 7a.

[1] 增城(縣) [2] 盡伐 [3] 白蕉 [4] 香牙蕉 [5] 蜜桔
[6] 芋 [7] 薥 [8] 蕉 [9] 相代而生

(x) *Intercropping*

As pressure on land increased, and the need to obtain the greatest absolute return arose, the natural thing to do in the absence of improved cultivars, was to utilise the land continuously for as much of the year as possible by rotating crops. The next step in the intensification of agriculture was to intercrop sugarcane[a] with food and fibre crops such as peanuts, rice, sweet potatoes and cotton. The earliest known reference to intercropping of any kind in China occurred in the +14th-century *Nung Thien Yü Hua*[1], which related that rows of late rice were grown between rows of early rice.[b] However, the line in the *Thang Shuang Phu* of c. +1154: 'Sugarcane is most dependent on the fertility of the soil, and cannot be mixed with other crops'[c] could mean that agriculturalists practised intercropping during the +12th century, but that the author did not regard it as appropriate practice for the cultivation of sugarcane. Apart from loss of fertility, an additional reason could be that intercropping proved difficult to implement with the narrow 31 cm inter-rows in the furrow and ridge systems discussed earlier; the sugarcane would crowd out the interplanted crop before it had matured. I hypothesise that it was necessary for the inter-rows to increase to 90 cm, as shown in the *Thien Kung Kai Wu* of +1637, before intercropping became economically feasible with sugarcane. This hypothesis is supported by the history of Barbados where intercropping became possible in the late +17th century, when planters increased the distance between the holes in which sugarcane was planted, thus enabling crops to be planted on the intervening banks.[d] In addition, 20th-century Indian agronomists have found it necessary to widen sugarcane rows for intercropping.[e]

In China the first literary description of intercropping with sugarcane occurred with cotton in the +1686 gazetteer for Phan-Yü county[2], near Kuang-Chou in the Pearl River delta region:[f]

> When the county people plant [they] remove the tops of the sugarcane, cut them into [pieces] of approximately 2 or 3 *tshun*[6–9 cm] and plant them amongst the cotton (*chi pei*[3]) during the second lunar month. When it comes time to pick the cotton, the sugarcane has already grown [to a height of] several *chhih* [approx. 64–96 cm]. During the tenth lunar month it is harvested, and the juice pressed and boiled to make sugar. This type [of sugarcane] is called bamboo cane (*chu-chê*[4]).

In this intercropping cycle agriculturalists picked the cotton in the sixth lunar

[a] Alternate terminology: interplant or companion crops.
[b] See Vol. 6, pt 2, p. 432, fn. e.
[c] *TSP*, p. 3b.
[d] Watts (1), p. 150.
[e] Babu (1), p. 183.
[f] +1686 *Phan-Yü HC*, ch. 15, p. 14a.

[1] 農田餘話 [2] 番禺縣 [3] 吉貝 [4] 竹蔗



Fig. 52. Interplanting of sugarcane between each four rows of rice near Hu Wei, Taiwan. After harvesting the rice, sugarcane cultivation commences with the mould-board plough; from Humbert (1), p. 95, fig. 52.

month before the sugarcane grew too tall.[a] A Japanese agronomist described sugarcane/rice intercropping in Taiwan early in the 20th century.[b]

In the early interplanting, rice plants are set in July, keeping the planting rows twenty-five centimetres apart, and saving one row alternatively in four rows for the cane planting [see Fig. 52]. When the rice comes to the stage of heading, seed canes are planted in the rows formerly prepared, at the rate of 23,000–25,000 per hectare; a little more than in the single-crop planting. After the planting of seed cane and until the harvest of the rice, irrigation water is withheld to avoid an unfavourable influence on the growth of the rice plants. General procedures, such as tillage, dressing and hilling, are carried on in the same way as when the cane alone is planted.

No comment was offered on the antiquity of these methods, but Japanese agronomists implied that they helped to improve traditional methods rather

[a] +1686 *Phan-Yü HC*, ch. 15, pp. 19b–20a. Intercropping of other crops with cotton was a very common practice, see Nishijima (1), pp. 36–9; Vol. 6, pt 2, p. 539.

[b] Fukuchi (1), p. 276.



Fig. 53*a*. Intercropping of sugarcane and sweet potatoes, Hu Wei, Taiwan. As sweet potatoes became a major food for sugarcane growers in China from the +17th century, the sweet potato/sugarcane intercropping system provided farmers with insurance against the vagaries of the market. It gave them a reliable supply of subsistence food which they could always fall back on when the market fluctuated, as it was often apt to do; from Humbert (1), p. 95, fig. 53.

than create new ones.[a] There are basically two ways of intercropping: (1) by introducing sugarcane into an already established crop, and (2) by planting another crop on the inter-row ridges of sugarcane. A Japanese agronomist elaborated on the second type of intercropping in Taiwan during the late 19th century:[b]

In some sugarcane fields beans, sweet potatoes and other crops are intercropped [see Fig. 53*a*]. Since this [intercropping] is conducted in the interval from the time of planting the sugarcane until May or June, when its stalks and leaves begin to grow thick [filling up the space between the rows], they do not obstruct each other's growth.

[a] *Ibid.*, pp. 275–6.
[b] Hara (*1*), p. 13.



Fig. 53*b*. Intercropping of sugarcane and tobacco, Chang-Phu county[1], Fukien, January 1991. In this area cane setts are planted in the inter-rows during the winter, and the soil from the tobacco rows are hilled up onto the young cane after the tobacco leaves are harvested in April. The distance between cane row centres is 110 cm. Note that the man in this photograph is using a hoe to fashion the furrows for planting the cane setts; orig. photo Christian Daniels.

[1] 漳浦縣

Growers planted beans and sweet potatoes on the mounds between the cane rows and harvested before the sugarcane leaves covered the inter-rows.[a] They actually arranged cane fields to accommodate both crops in an efficient manner; after harvesting the sweet potatoes and other crops planted on the raised mounds in between the rows of sugarcane, they hoed the soil on the mounds onto the sugarcane plants on either side.[b] In other words, the mounds in the inter-rows provided soil for ridging onto the cane setts when they began to grow taller, so intercropping was a strategy designed to utilise this soil until it became needed (see Fig. 53b). Peanuts, beans and other crops were commonly intercropped with sugarcane during the 1930s.[c] It should be remembered that intercropping was a common feature of Chinese agriculture, and was not peculiar to particular sugarcane-growing zones. During the +18th century in Jui-Chin county[1], Chiang-Hsi peasants grew food crops such as yams (*shu*[2]: *Dioscorea* spp.), dry taro (*han-yü*[3]: *Colocasia* spp.) and ginger (*chiang*[4]: *Zingiber officinale* Rose) between rows of tobacco.[d] Though no references date earlier than the +19th century, it seems that the most popular crops for intercropping with sugarcane from the +18th century onwards, were sweet potatoes, peanuts and beans, rather than cotton.

The question arises as to how sound intercropping was, could it be that vigorous competition between the intercrop and sugarcane caused the yields to fall so low as to create a nett economic loss? There is considerable modern literature on this subject, and numerous field trials have been conducted in China,[e] Taiwan[f] and elsewhere.[g] All situations demonstrated a nett economic gain, though in some cases there was a slight loss or gain in yields of sugarcane;[h] the gains mostly occurred with leguminous crops such as peanuts. Blume summarised the situation succinctly.[i]

> The sugarcane yield will not be reduced if intercropping is practised properly. Properly means that the planting of cane and other crops is timed in such a way that there will be no competition for nutrients between sugarcane and the respective crops.

In China intercropping commenced by the +17th century, if not before, and it remained the preserve of the area influenced by Chinese culture until the 20th

[a] These methods were most common practice, and contrasted with cultivation on badly drained soils in south China, where the sugarcane was planted on the ridges and the intercrop in the furrows. In the 20th century, on the coastal lowlands of the Pearl River delta, sugarcane is planted on the ridges and intercropped with soybeans and peanuts in the furrows, see Blume (1), p. 243.

[b] Personal communication from Wu Mi-Cha, Lecturer in History at Taiwan National University, 1986.

[c] See Vol. 6, pt 2, p. 432 for peanuts and Kanda (1), p. 524 for beans and wheat crops in Ssu-Chhuan.

[d] Tajiri (2), *ge*, pp. 14–19.

[e] Chan (1).

[f] See Liu, K. C. (2) for five papers on various aspects of intercropping, Tse & Shiue (1), and Humbert (1), pp. 94–5 for a summary of research with excellent photographs.

[g] See review in Blume (1), pp. 75–6.

[h] The net profit of interplanting rice, legume or sweet potatoes with cane planted in autumn ranges from 12% to 34%, Tse & Shiue (1).

[i] Blume (1), p. 76.

[1] 瑞金縣 [2] 薯 [3] 旱芋 [4] 薑

century when favourable reviews from Japanese, and lately American, agronomists directed attention to its utility. In 1968 Roger Humbert, commenting favourably on intercropping in Taiwan, wrote: 'This more extensive use of the land will be more widely used in the future as the world's expanding population demands more food and fiber.' Sixteen years later Blackburn recorded intercropping in peasant agriculture in Mauritius, India, Indonesia and Pakistan.[a] This Chinese contribution to Asian sugarcane agronomy and food production will continue to have far-reaching effects.

In China itself, the intercropping and rotation of sweet potatoes with sugarcane was a particularly important factor behind the increase in sugar production in China after the +17th century, for these cultivation practices provided cane growers with a source of food free from the vagaries of the grain market. In other words, these practices enabled cane growers to participate in commodity production, and simultaneously maintain a self-sufficient food supply which they could always fall back on when the market failed them. The adoption of such intensified sugarcane cultivation practices was the Chinese cane growers' answer to the problems posed by their increasing dependence on the market after the +16th century.

(xi) *Pests, diseases, and acts of God*

Diseases

As far as we are aware China remained remarkably free from any serious outbreaks of sugarcane diseases until the introduction of new clones in the 1980s.[b] The only mention of sugarcane disease I have been able to find appeared in the Chinese *Tripitaka.* It occurred in a Chinese translation of a *Mūlasarvāstivāda* text, the *Vinayak sudrakavastu*, rendered by the monk and great traveller I-Ching[1] in +710.[c] The story was first discovered in a Pāli Buddhist text by Nöel Deerr, and deserves quoting for its information on cane diseases, and the Buddha's views on the admission of women to holy orders. Mahaprajapati, the foster-mother of Rahula, the Buddha's son, requested that the Buddha allow women to initiate an order of nuns. After a first refusal, she again urged

[a] Blackburn (1), p. 157. This innovation was unlikely to have evolved in India and Pakistan where sugarcane was not planted in rows until the +19th century. I have found isolated cases in India in the late +19th century where crops such as opium were sown over a sugarcane crop, see Watt (1), vol. 6, pt 2, pp. 180, 185, 198, 204. Sugarcane has been promoted by 20th-century Indian agronomists as a true intercrop; it is significant that they recommend widening the rows for intercropping, see Babu (1), p. 183. In Indonesia and Mauritius which had European-dominated plantation systems, intercropping systems had to await independent governments with different priorities.

[b] See Martin, Abbott, and Hughes (1), Hughes, Abbott and Wismer (1), and Sivanasen and Waller (1) for descriptions of sugarcane diseases of the world. In ISSCT Standing Committee on Sugar Cane Diseases, 1980–1983 (1), there is a check list of sugarcane diseases and disorders and their distribution by countries, as recognised by the International Society of Sugarcane Technologists.

[c] Taishō no. 1451, Nanjio no. 1121.

[1] 義淨

her request supported by Ananda, the favourite disciple of the Buddha. The Buddha at last relented, but with the admonition:[a]

> Just as when the disease known as *manjitthika* falls on a field of ripened sugar-cane, that field does not last long, even so, Ananda, in whatever discipline of *Dhamma* women are allowed to go forth from the home to the homeless life, that godly life will not last long.

Deerr added a footnote about the word *manjitthika*:

> This word means 'colour of madder'. Madder or *manjit* is a native to, and still used as a dye in India. It affords the deep red dye known as turkey red. The most widespread cane disease is that known as 'red rot', caused by the fungus *Colletotrichum falcatum*.[b] At the time of writing it is very prevalent in the area where the Buddha came to this decision. A feature of the disease is that often it only makes itself manifest when the cane is ripe for harvest. It does not, then, seem unlikely that this is the very disease referred to by the Buddha, and that the passage forms the first mention of a cane disease.

The Chinese translation by I-Ching helps in the diagnosis. In it the story ends: 'Again Ananda, it is like a field of ripe sugarcane being completely devastated by red internode disease (*chhih-chieh-ping*[1]).'[c] As the brightly coloured red rot of the cane joints (node plus internode) is the essential feature of the disease, I-Ching's descriptive name makes it certain that the sugarcane disease was red rot, *Glomerella tucumanensis* (Speg.) Arx and Muller, which pathologists have also recorded for China.[d]

In the 1980s more than twenty diseases were recorded in China, all of which had not been considered problems in the past.[e] The following factors contributed to this satisfactory state of affairs. First, in the past, the major commercial clones were of the species *S. sinense* and possibly *S. barberi*, which are resistant or tolerant to a great number of diseases, but now have been replaced with introduced or locally bred hybrid clones.[f] Most of the diseases noticed at the moment: clumicolous smut,[g] leaf rust,[h] eye spot,[i] and yellow

[a] Deerr (1), p. 43.

[b] My note: *Colletotrichum falcatum* is the imperfect stage of the fungus *Glomerella tucumanensis* (Speg.) Arx and Muller.

[c] Taishō no. 1451, p. 350; Daniels & Daniels (6), p. 18.

[d] It has a wide distribution in Yunnan, see Khun-Ming Tung-Chih-Wu Chien-I-So (1), p. 33.

[e] Blume ((1), p. 242) consulted technologists in China in 1983 and recorded 22 diseases, but diseases were not named apart from smut, rust and ratoon-stunting diseases. The listing of the International Society of Sugarcane Technologists in 1983 recorded 15 diseases with their complete designations, see ISSCT Standing Committee on Sugar Cane Diseases, 1980–1983 (1), p. 51. Also see Chhing Kung Yeh Pu ... (1).

[f] Abbott (1), p. 419; Sreenivasan, Ahloowalia and Heinz (1), p. 215 in Heinz (1).

[g] *Ustilago scitaminea* H. Sydow. Reported as a problem in upland areas in southern China by Blume (1), p. 242, and has a wide distribution in Yunnan province according to Khun-Ming Tung-Chih-Wu Chien-I-So (1), p. 33. Smith, Dudley (1) reports that this disease occurred in *S. sinense*, which undoubtedly served as a source when susceptible clones were introduced in recent years.

[h] *Puccinia melanocephala* H. & P. Sydow apud H. & P. Sydow & E. Butler, and *P. kuehnii* E. Butler. Blume ((1), p. 242) reported an outbreak on Hainan island.

[i] *Drechslera sacchari* (E. Butler) Subram. & Jain; formerly *Helminthosporium sacchari* E. Butler apud Butler and Khan. Wide distribution in Yunnan, see Khun-Ming Tung-Chih-Wu Chien-I-So (1), p. 33.

[1] 赤節病

spot[a] also became prominent in other parts of the world with the advent of hybrid clones. Second, historically speaking, only a small number of clones were introduced into China, which meant that China enjoyed fewer chances for the import of diseases than other parts of the world. In fact, China did escape the troubles of European plantation systems in which diseases arrived with exotic clones introduced to raise productivity. Third, the tendency not to ratoon, especially in the growing areas north of the ranges, gave breaks in the crop cycle which acted to control the build up and spread of diseases. In conclusion, this recent profusion of diseases has resulted from a change of germplasm through the introduction and breeding of hybrid clones.[b] It has been revealed that a virus, Fiji disease, has been accidentally introduced into south China from Thailand with a shipment of new clones, thereby illustrating this point.[c] Also Taiwan has over twice as many diseases as China,[d] a situation which undoubtedly arose from the Japanese colonial administration inadvertently encouraging the import of susceptible clones from outside,[e] and the early establishment of breeding programmes on the island.[f]

Pests – insects

Insect pests of sugarcane in China number over 300 species, 130 of which only occur in Kuang-Tung, indicating localisation of minor insects over the whole Chinese sugarcane area. The most important insect pests are:[g]

1 Sugarcane moth borers, arranged below under the part of the plant they *usually* invade. Some species such as *Chilo infuscatellus* attack the whole plant.

– shoot borers	*Argyroploce schistaceana* Snellen
	Sesamia inferens Walker
– internode borers	*Chilo auricilus* Dudgeon
	Chilo venosatus Walker
– top borer	*Chilo infuscatellus* Snellen

[a] *Mycovellosiella koepkei* (Krüger) Deighton; formerly *Cercospora koepkei* Krüger. Khun-Ming Tung-Chih-Wu Chien-I-So (*1*), p. 33 indicates a wide distribution in Yunnan province.

[b] For example smut was at a low level world-wide in the pre-hybrid era as *S. officinarum* canes are generally resistant, see Antoine (1), p. 345.

[c] Chou, Hsieh, Lin, Tshai and Wang (*1*). This is potentially a very dangerous situation as the insect vector of the disease *Perkinsiella saccharicida* Kirkaldy, known as *chê-fei-shih*[1] in Chinese, is indigenous to south China. Fiji disease causes severe stunting or stool failure in susceptible clones.

[d] The published list of sugarcane diseases and disorders lists 15 for China and 58 for Taiwan, see ISSCT Standing Committee on Sugar Cane Diseases, 1980–1983 (1), pp. 51 and 59–60.

[e] Downy mildew was first observed in Taiwan in April 1909, in a section of a field on the sugar experiment station 'occupied entirely by Australian canes'. Miyake through Hughes and Robinson (1), p. 142.

[f] The Japanese established a sugarcane experiment station in Taiwan in 1903 to introduce sugarcane clones and later to commence breeding, see Wu (*1*), p. 10; sugarcane breeding in China commenced with the Peoples Republic of China in 1949, see Chen, Ching-Long (1).

[g] Liu, Sun, Wang & Liu (1), p. 217. The Latin binomials have been standardised on the study of Williams, Metcalfe. Mungomery & Mathes (1), published under the auspices of the International Society of Sugarcane Technologists, which remains the standard text on sugarcane entomology. Also see Chhing Kung Yeh Pu ... (*1*).

[1] 蔗飛虱

2 The sugarcane white grub (beetle in adult)
Alissonotum impressicolle Arrow.[a]

3 The sugarcane woolly aphis
Ceratovacuna lanigera Zhnt.

4 The sugarcane mealy bug
Saccharicocus sacchari Ckll.

5 The sugarcane leafhopper (the vector of Fiji disease [virus])
Perkinsiella saccharicida Kirkaldy.

6 The sugarcane thrip
Fulmekiola serratus R. & M.

Entomologists currently working in Kuang-Tung consider the first three groups the most serious.[b] In recent years considerable effort has been exerted to control biologically stem borers with the egg parasite *Trichogramma* spp.[c] These efforts have been successful, along with pheromone attractants against the borer *Chilo infuscatellus*.[d]

Chinese sources contain no records of large disasters attributable to insect pests. This was no doubt due to the hardiness and vigour of *S. sinense* and *S. barberi* clones which helped minimise losses in the past. The first reference to pests in cultivated sugarcane in China appeared in the account of Jean Nieuhof in the mid +17th century.[e]

> Immediately when the plant appears it must be thoroughly groomed by hoeing all the surroundings so that aggressive weeds will not suffocate it. But from the time it covers the ground, it conserves itself and is able to survive many years without being renewed, provided that the worms are not in it. It is best in this case to uproot immediately all the plants and plant anew.

I speculate that this is the first mention of a sugarcane borer as the 'worm' is recorded in the plant itself. 'Worm' is descriptive of the larvae of the moth borer that is so evident in damaging the plant.

White grubs (*Alissonotum impressicolle*) do have a place in sugarcane history, paradoxically as a food eaten roasted rather than recognised as a pest. The +1762 gazetteer for Hai-Chheng county[1], in Chang-Chou prefecture[2], Fukien remarked:[f]

[a] White grubs in sugarcane in Chheng-Tu, Ssu-Chhuan, have been identified as *Alissonotum parvum* in Chang Yu-Wei (*1*).

[b] Liu, Sun, Wang & Liu (1).

[c] *Ibid.*, Chang Yu-Wei (*1*).

[d] Wu, Yan, Wang, and Huang (*1*).

[e] Nieuhof (1), pp. 89–90. Worms eating sugarcane were described for Jamaica in the early +18th century, see Sloane (1), vol. 2, p. 220.

[f] +1762 *Hai-Chheng HC*, ch. 15, p. 34b. The following gazetteer for Chhao-Chou prefecture, a large, +19th-century sugar-producing region in north-eastern Kuang-Tung, described a wingless variety. In the +1890 *Chieh Yang Hsien Hsü Chih*, ch. 4, *wu-chhan*, p. 37a it is written: 'Sugarcane Insect (*chê chhung*[3]). It is a sugarcane borer (*chê chih tu*[4]) born inside the roots of sugarcane. It resembles a honey bee, but has no wings or sting.' An *(cont.)*

[1] 海澄縣 [2] 漳州府 [3] 蔗蟲 [4] 蔗之蠹

Sugarcane beetle[a] (*chê chhan*[1]). It is a type of beetle that is born inside the roots of sugarcane. Dry [the grubs that] have not exuviated in the sun, and taken as an article of food they are exceptionally excellent.

This text exhibited some understanding of the life cycle of *Alissonotum impressicolle*. The white grub passes through three stages of growth, the skin moulting at each stage. In the third stage an earthern cell is made in which pupation occurs. Transformation to the adult stage takes place in this cell, and the beetle emerges when conditions are favourable.[b] As the earlier +1633 gazetteer for Hai-Chhêng county did not mention the white grub, this is the first known literary reference to them in China. At the end of the +18th century Sir George Staunton observed people cooking and eating as 'a dainty' large white grubs found under the roots of the sugarcane in Hangchow prefecture, Chekiang.[c]

Shih Hung-Pao[2] in his *Min Tsa Chi*[3] of c. +1845 to +1856 wrote of Fukien province.[d]

Sugarcane Insect (*kan chê chhung*[4]). During the second and third lunar months raw and cooked sugarcane insects, which are born in the old roots of sugarcane are sold in the markets everywhere in Chang-Chou[5] and Chhüan-Chou[6] prefectures. When born they resemble silkworms, but thin, ash white in colour and smooth and glossy with no fine hair. After the cooked ones are roasted with oil [their legs] curl up like those of bees, and [they turn] light yellow in colour. The flavour is exceptionally delicious and crisp, and it is especially excellent as a relish accompanying wine.

Commentary: Sugarcane has algorific properties (*hsing han*[7]). [A line] in the poem *Hsieh Tzhu [Pai Kuan] Ying Thao*[8] of the ancient Wang Wei[9] [+701 to +761] reads:

> In overeating you need not worry about internal calefacience (*nei-jê*[10]): The official in charge of the Emperor's food and drink (*Ta Kuan*[11]) has sugarcane syrup which is algorific.

As this insect is born inside sugarcane, it must also have algorific properties. Doctors in my native area [Chhien-Thang county[12], Chekiang] use the sugarcane insect a lot when the syrup (*chiang*[13]) for curing children's smallpox will not rise, so it seems that it has calefacient properties as well. It is not recorded in the Pharmocopoeias (*Pen Tshao*[14]), and is not able to be identified.

Since Shih Hung-Pao stated that the medicinal effects of these grubs do not appear in the pharmacopoeias, especially the celebrated *Pên Tshao Kang Mu* of

Footnotes to page 260 (*cont.*)

illustration in a modern Chinese handbook, 14–C3 in Chhing-Kung Yeh Pu ... (*1*), depicted a wingless male imago. The +1900 *Hai Yang HC*, ch. 8, p. 9a recorded that sugarcane insects were called *chê thou kuei*[15] (literally sugarcane head tortoise) in the local dialect.

[a] Literally, cicada.
[b] Wilson, G. (1), p. 241.
[c] Staunton (1), vol. 3. p. 294. These grubs were cooked in oil.
[d] Shih Hung-Pao (*1*), pp. 184–5.

[1] 蔗蟬 [2] 施鴻保 [3] 閩雜記 [4] 甘蔗蟲 [5] 漳州
[6] 泉州 [7] 性寒 [8] 謝賜[百官]櫻桃 [9] 王維
[10] 內熱 [11] 大官 [12] 錢塘縣 [13] 漿 [14] 本草
[15] 蔗頭龜

+1596, they were evidently a new preparation. White grubs presumably appeared in +18th-century sources because this is possibly the period when sugarcane growing expanded onto marginal land infected by *Alissonotum impressicolle*; one would not expect to find the white grub inhabiting the delta areas as it would be eradicated by periodic flooding.

Finally let us look at other types of care advised for sugarcane standing in the field. The *Kuang Tung Hsin Yü* of +1700 advised: 'Once the stalks have grown, [work] day and night to wipe off the caterpillars (*tshu*[1]), peel off the trash (*man*[2]) and sheaths and the sugarcane will flourish.'[a] Chhu Ta-Chün[3], the author of this work, stressed the importance of removing trash and insects. Peeling off trash is practised in a number of peasant agricultural systems, but no yield increases have been demonstrated.[b] However, it is recommended by modern Chinese entomologists for controlling mealy bugs, leaf hoppers and thrips.[c]

Pests – rodents

Rodents cause appreciable losses to crops in most countries of the world and constitute a very serious pest of sugarcane.[d] Although many rodents attack sugarcane only rats, the 'whisker'd vermin race' of James Grainger in his *The Sugar-Cane* of +1764, usually create problems.[e] I have not been able to find any incidences of rat damage in Chinese sources, except an intriguing story of a spiteful eunuch who adulterated some amorphous sugar (*kan-chê hsing*[4]) presented by Chiao-Chou[5] in north Vietnam, or according to another version honey, with rats' excreta in order to dishonour the official in charge of the Palace Storehouse in the eyes of the sovereign of Wu[6] in +257, but in any case it

[a] *KTHY*, p. 689.

[b] See the review in Deerr (2), pp. 134–5 which showed that the results of trash peeling are very variable.

[c] Liu, Sun, Wang & Liu (1), p. 219. It is of interest that they also recommended intercropping for insect control to aid in providing a good habit for natural enemies.

[d] See Bates (1); Blackburn (1), pp. 208–14.

[e] The sugarcane rat is the subject of one of those anecdotes that enliven the history of English literature. Dr. James Grainger (+1723 to +1767), a medico of literary bent, spent several years on the island of St. Christopher in the Caribbean. After about three years he returned to London temporarily with the manuscript of *The Sugar-Cane*. James Boswell divulged in his life of Johnson that when *The Sugar-Cane* was read in manuscript at Sir Joshua Reynolds', the assembled wits burst into laughter when after much blank-verse pomp, the poet began a new line with: 'Now, Muse, let's sing of rats'. And what increased the ridicule was, that one of the company, who slyly overlooked the reader, perceived that the word had originally been 'mice' and had been altered to 'rats' as more dignified. This passage does not appear in the printed work, as Dr. Grainger, or some of his friends, it would seem, became sensible that introducing even *rats* into a grave poem, might be liable to banter. He, however, could not bring himself to relinquish the idea: for they are thus, in still more ludicrous manner, periphrastically exhibited in his poem as it now stands: 'Nor with less waste the whisker'd vermin race, / A countless clan despoil the lowland cane.' See Chalmers, Alexander (1), vol. 14, for the most accessible source of *The Sugar-Cane* (pp. 478–511) and a life of Grainger (pp. 469–474) which contains the quote from Boswell (pp. 472–3), and for the original see Boswell (1), pp. 593–4. *The Sugar-Cane* and this anecdote are evidence of the intellectual climate of +18th-century Europe into which we will be trying to trace below a possible infusion of Chinese sugarcane agriculture and technology. In +18th-century England, agriculture was accepted as a serious subject worthy of study by the aristocracy, the intellectuals, and even the wits at Sir Joshua Reynolds' soirées.

[1] 蟊 [2] 蔓 [3] 屈大均 [4] 甘蔗餳 [5] 交州
[6] 吳

was not sugarcane.[a] However, we have considerable information from Taiwan where Takano & Kondo recorded an exception to the rule of the 'rat', the indigenous bandicoot *Bandicota nemorivaga* Hodgson, which constituted the most serious rodent pest in the early +20th century.[b] They listed, in addition, two species of rats, *Rattus norvegicus* Erxleben, *R. losea* Swinhoe, and two of mice, *Apodemus agriarius ningpoensis* Swinhoe and *Mus formosanus* Kuroda. *B. nemorivaga* and *R. losea* were listed as the most serious pests with four major features of damage:[c]

1 Digging up and devouring setts in newly planted fields
2 Attacking and destroying the growing points of young cane
3 Burrowing under stools and feeding on underground sprouting shoots
4 Gnawing the internodes of mature cane which often resulted in broken stalks.

The fourth item was the most visible, and the damage was compounded by secondary infection of the red rot fungus (*Glomerella tucumanensis* [Speg.] Arx and Muller) which was also very conspicuous.

Rodents were certainly a problem of some antiquity as most genera of the rodents were indigenous to Taiwan. Takano & Kondo described how 'native' traps were constructed and operated (see Fig. 54).[d] They listed other measures, probably indigenous, which included cage-traps with baits, use of dogs, and harvesting fields towards a man-made pit where rats were trapped and clubbed to death. In 1933–4 two million rats were exterminated in Taiwan, and it is estimated that about 7,000 tons of cane were lost. The most severe losses occurred alongside water courses and waste land where rats harbour.[e] There is little doubt that, although rats have caused some damage in sugarcane-growing areas in China from the earliest times, losses were probably minimised by the growing of tough, high-fibred *Saccharum sinense* clones.

Acts of God

For completeness we direct attention to two problems, typhoons and floods, which must have caused severe losses from earliest times. Typhoons are a great hazard from July to September in the southern zone, and Liu[f] reported that 218 typhoons were recorded in Taiwan during the period 1897 to 1956. This indicates a major problem, as wind speeds as low as 50 km per hour cause damage, and most typhoons attain 100 km per hour or more.[g] For instance, a typhoon which hit Fukien in July 1982 destroyed 30 per cent of the sugarcane crop.[h]

[a] For the *kan-ché hsing* presented by Chiao-Chou see the *NFTMC, shang*, pp. 4b–5a of +304, but the *Tzu Chih Thung Chien*, p. 2436 only mentioned honey.
[b] Takano & Kondo (1), p. 106.
[c] *Ibid.*, p. 107.
[d] *Ibid.*, p. 109.
[e] *Ibid.*, pp. 109–11.
[f] Liu, K. C. (1).
[g] Blume (1), p. 57.
[h] *Ibid.*, p. 239.

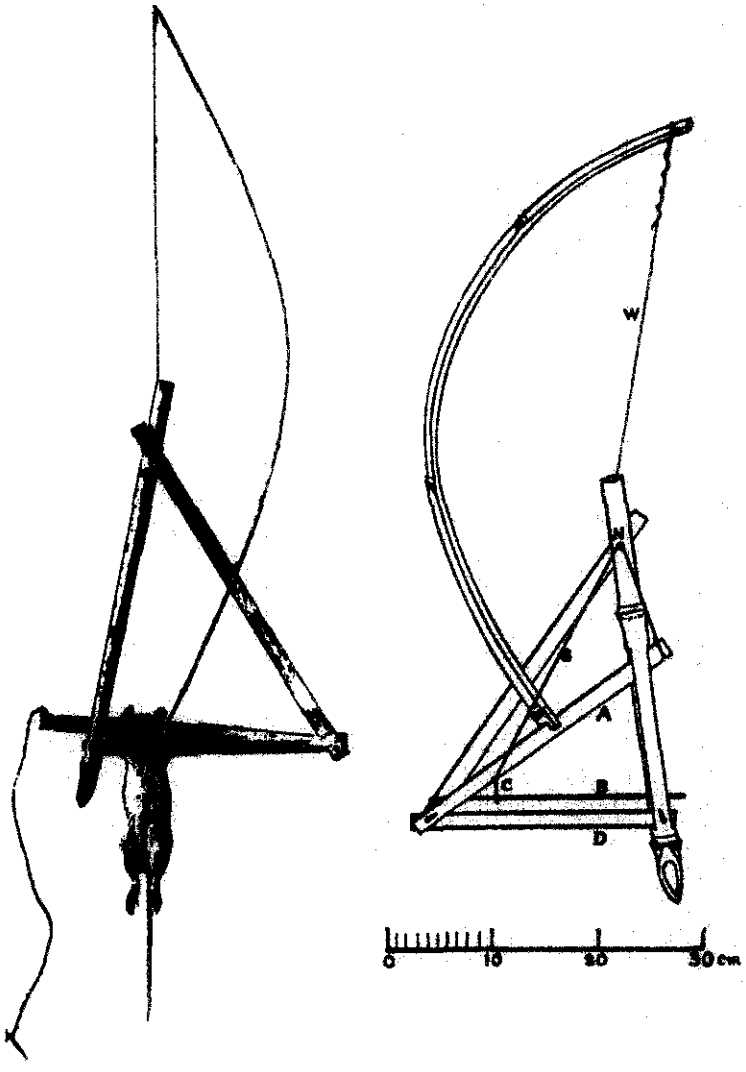


Fig. 54. A bow-trap for catching members of Grainger's 'whisker'd vermin race' in sugarcane fields in early 20th-century Taiwan. When the rat passes through A and B, its body presses down on B. C is then drawn from the catch so that S becomes loose and A falls with a powerful blow, catching the rat between A and D. This is indigenous equipment of unknown antiquity; from Takano & Kondo (1), p. 110, figs. 2 and 3.

High wind can cause four kinds of damage: first, breaking and death of stalks; second, lodging and uprooting of cane, resulting in dead and light cane; third, lower sugar content in dead and rotten stalks, and fourth, damage by excessive water accompanying the storm. There is considerable resistance to typhoon damage between clones, and the tough *khun-lun chê* and *Saccharum sinense* helped minimise damage in the past.

Floods constituted a problem in the lowland coastal delta regions where drainage was difficult. In these areas sugarcane was planted on the tops of ridges rather than in the furrows to aid the root systems. Sugarcane exhibits

surprising resistance to periods of immersion providing silt is not deposited in the growing points. In the last 350 years sugarcane growing has expanded onto hillsides where soil erosion has replaced flooding as a problem. Erosion has been controlled first by large-scale terracing, and second by retaining the tops and leaves of harvested sugarcane as ground cover after harvesting the stalks.

(5) Conclusions on Agriculture

Sugarcane was a cultigen of the Yüeh tribes in south China, and as well as a food, it featured in religion, magic, medicine and on ceremonial occasions, as elsewhere in South-East Asia, Indonesia and the Pacific. This wider cultural spectrum refuted the concept of sugarcane as a recent introduction into China; the Han Chinese found this plant used as an indigenous cultigen when they invaded south China about −200.

It took over one thousand years for the commodity production of sugar to emerge in the southern zone; long distance trade in large quantites of sugar only began during the Sung. The Yüeh peoples displayed great reluctance to engage in market-oriented agriculture, and they revolted against 'sinicisation' on numerous occasions. Sugar production for the long-distance market increased with the assimilation of the Yüeh into the Han Chinese tenant and landlord system. The dilution of Yüeh genes with intermarriage and the influx of Han Chinese refugees from north China assisted the establishment of stable agricultural communities by the Sung. Agricultural techniques practised south of the ranges largely derived from the Yüeh, sugarcane being grown on spaced mounds or holes depending on moisture conditions. Growers cultivated with the hoe, and also adopted appropriate southern zone methods of manufacture which we shall explore below. These procedures continued until the +17th century when ridge and furrow, and mould-board plough regimes were introduced from the northern zone via Fukien. Fukien, an early centre of innovation, had a large Han Chinese population from the Sung dynasty, and as such may be considered atypical for the southern zone and more akin to the northern zone.

Chinese sources mentioned no major outbreaks of disease or pests. This probably arose for a number of reasons: first, the tolerance of *S. sinense* clones to adverse conditions, diseases and pests; second, the isolation of China from sugar production in other parts of the world, in particular the plantation activities of European planters after the +17th century;[a] third, the implementation of agricultural practices such as not ratooning in some districts, a strategy which served to break pathogen and pest cycles with clean seed on replanting.[b]

North of the ranges, sugarcane agriculture also took time to get underway as

[a] Taiwan was not as fortunate as the mainland because Japanese activities ensured that there are now twice as many diseases in Taiwan than China.

[b] This applied more particularly to the northern zone. Other agricultural practices controlling diseases included pre-germination and transplanting for obviating soil borne diseases. Intercropping of peanuts and other legumes helped multiply parasites of insect pests.

the climate presented significant problems. First, clones suitable for the colder climate had to be found. Since the noble cane, *S. officinarum*, faired poorly under the harsh conditions, *S. sinense* had to be adopted for the scale of cultivation to achieve any magnitude. Second, agriculturalists overcame limitations imposed by frost on storage of seed cane for planting in spring and by adopting the traditional Chinese strategy of air-tight subterranean pits.

I suggest that commodity sugar production commenced north of the ranges in Thang/Sung times after a period of experimentation which extended back a few centuries. When the *Thang Shuang Phu* of c. +1154 first documented sugarcane agriculture for the northern zone, it displayed surprisingly 'modern' features. The fields were ploughed flat as in other areas, but then moulded and the setts planted in furrows about 31 cm apart with an inter-row ridge, rather than in holes on raised beds as in the Islamic World, or by broadcast distribution as in India. The Chinese established the young crop by hand watering or irrigating down the rows, and controlled weeds by hoeing; this contrasted with flood irrigation in India and sub-surface irrigation in the Islamic world. Irrigation down the row marked a big advance in the efficient use of irrigation water.

In the late +16th century we witness a significant development for world sugarcane agriculture in China. Growers widened the inter-rows to about 1.2 m, and controlled weeds mainly by cultivating the inter-rows with a mould-board plough, supplemented by hoeing of the rows, if necessary. They ran the mould-board plough close to the row, ploughing away to the inter-row, then, as appropriate, made a pass down the centre of the inter-row with the mould-board, throwing the soil towards the rows; they repeated the operations as necessary. In addition, the new method provided the first adequate basis for ratoon agriculture; the soil ploughed away from harvested cane rows could be loosened up and made friable. The furrows obtained by this ratoon cultivation could also be utilised for irrigation. This system formed the basis of agriculture in Louisiana, South Africa, Australia, Fiji and elsewhere prior to the advent of disc cultivators and herbicides. We shall discuss possible avenues of transmission later.

These new mould-board ploughing techniques had several beneficial effects in the Chinese sphere of influence. First, the widened inter-rows facilitated intercropping with other food crops, thus strengthening the subsistence base of sugarcane growers. This permitted sugar production to expand in conjunction with the rise of the money economy from the +16th century. Second, the mould-board plough methods allowed the efficient scaling up of operations, enabling Chinese immigrants overseas to undertake larger-scale agricultural operations than possible at home.

Mould-board plough cultivation was not a completely new system as, in reality, it merely applied the ancient horse hoeing techniques of China to perennial crops using a mould-board plough. The horse hoe reached the realms of a fine art in China by the +6th century,[a] but we do not know whether these tradi-

[a] Vol. 6, pt 2, p. 308.

tional implements found use in sugarcane fields before the mould-board plough in the late +16th century. I hypothesise that they were not applied, and that growers initiated the mould-board regime to plough out intercrops rather than as a horse hoe operation. Intercropping appeared about the same time; in fact rows were originally widened to accommodate the intercrop. After harvesting, the intercrop residues had to be incorporated into the soil, and cultivation of the sugarcane crop commenced as rapidly as possible. The mould-board plough was the ideal implement for the job, and I suggest this as a scenario for the introduction of mould-board, horse hoeing in China.

The pre-Sung method of ridge and furrow persisted side by side with the new, +16th century wider row, mould-board plough technique, because it had three advantages. First, on hillsides a minimum spacing of 31 cm helped control erosion by providing a dense mass of vegetation that covered the inter-rows earlier. Second, the earlier covering of the inter-rows reduced the need for weeding. Third, it proved a most effective method if sufficient animals were not available, a common situation in south China. Thus the Chinese possessed two basic agricultural strategies, (1) ridge and furrow and (2) mould-board plough cultivation, for coping with variations in physical conditions and labour supply.

The Chinese also possessed an improved planting method. By the late +16th century agriculturalists had adapted traditional rice transplanting techniques to sugarcane. They planted single eye setts *en masse* on raised beds two months ahead of field planting, and at the appropriate time transferred the cane seedlings into the field and irrigated them. This procedure circumvented early spring cold and drought by setting in fields young plants that were already growing vigorously and past the long juvenile phase. In addition, there were no gaps in the cane rows, which helped to avoid pineapple disease, the soil-borne disease of newly planted setts.[a] Transplanting is still practised in China in some circumstances, and has been re-invented in Hawaii and India as +20th-century technology.

We must now consider the possible diffusion of the mould-board plough system and the ridge and furrow technologies from China to Europe and the New World. The system employing mould-board ploughs first appeared explicitly in the emerging industry of Louisiana about 1820:[b]

> The plow had been used to prepare the land from the earliest days of cane culture in the South, but in the beginning was used little during the period of cultivation. By the twenties, however, Anglo-American planters had begun to cultivate with the plow, and its use continued to spread during the next decades. One expert sugar planter in 1847 expressed the belief that the use of the plow would save almost three fourths of the weeding formerly done with the hoe; apparently all were convinced of its value as a labor saving device.

Of course, the increased use of the plow made it possible to enlarge the acreage

[a] *Ceratocystis paradoxa* (*Dadé*) C. Moreau, this pathogen also causes water blister and the soft rot of pineapples.

[b] Sitterson (1), p. 128

under cultivation per working hand. Harrows were widely used in conjunction with the plow in preparing the land. At the beginning of the nineteenth century, when virtually all the work during cultivation was done with the hoe, it was estimated that one field hand could take care of only three acres of cane. In the 1820s acreage per working hand had grown to just four acres. As a result of the more extensive use of the plow, in the next few decades this was greatly increased, until in the 1850s it was not unusual on many plantations for a field hand to cultivate nine or ten acres, although the average was probably somewhat less.

We are looking at a regime, first employed in China during the late +16th century, the advantages of which can be clearly quantified at about three times that of hand tools. It later spread from Louisiana to Australia, Natal, Fiji and numerous other countries. The concept of the light Chinese mould-board plough with its curved iron mould-board as a major input into the Agricultural Revolution of Europe has already been discussed in Volume 6, part 2.[a] It was concluded that:

> It appears likely that the Dutch saw Chinese ploughs at work in the rice-fields of South China – or perhaps Java or Japan – and were struck by their potential for use in the marshy lands along the Dutch coast. They adopted the main features of the Chinese plough in a new type which was first used in the boggy lands of West Holland and East Anglia, and soon afterwards came to be adapted for use on drier soils where it proved immensely successful . . . So although the new European plough was originally based on a Southern Chinese model, it soon came to be incorporated into a dryland system of drill-husbandry very similar to that of North China.

I consider it equally as likely, that Dutch observations of the mould-board plough in use on dry land sugarcane plantations in Java, the centre of the Dutch administration in Asia, also led to its transfer to the New World. This hypothesis has the advantage that it does away with the necessity of postulating a conscious adaption to dry land farming later in Europe as done previously. In addition, the observation of the Chinese application of the mould-board as a horse hoe could have been an input into the development of the concept of horse hoeing in Europe.

Jethro Tull (+1674 to +1741) is usually regarded as the person at the focus of the +18th-century European Agricultural Revolution in its cultivation aspects. While recovering from illness in the south of France, he observed peasant farmers tending their grape vines by cultivating the inter-rows with simple ard or scratch ploughs. He developed his system from this experience and probable observation of row culture in the low countries.[b] Tull advocated preparation of seed beds by mould-board ploughing, sowing seeds in rows with a drilling

[a] Vol. 6, pt 2, p. 582.

[b] Tull's experience in France is not documented in any way apart from his own works. Tull gave the impression that his system evolved from his observations of cultivation of a perennial crop, the vine. However, he could not have been unaware of vegetable crops grown and cultivated in rows. See Fussell (6) for a review of what little is known of the life of Jethro Tull.

machine and freeing the crop from weeds with inter-row horse-hoeing.[a] G. E. Fussell has put his achievements in perspective by pointing out that he had predecessors in all these spheres, but he was the first to combine them into a system that worked, about +1700. Tull adopted the English two-wheeled mould-board for land preparation, but had to invent a seed driller and horse hoe himself. His methods were fully operational, while there is doubt that his predecessors got much beyond illustrating ideas in books. We must stress that Tull needed to invent a horse hoe as there were no light swing ploughs in England for inter-row cultivation until the Rotherham, or Dutch plough of +1731. Jethro Tull was fortunate that his publication, *The Horse-Hoeing Husbandry or an Essay on the Principles of Tillage and Vegetation* in +1733, achieved wide international recognition very quickly. The Duc de Noailles sponsored a French translation of the *Essay* by a M. Otter which proved unsatisfactory. The famous French naturalist, George Louis Leclerc, Comte de Buffon, the translator of Newton's *Fluxions*, was asked to revise Otter's text, but refused to release it because he found it impossible to capture Tull's idiomatic English. In addition, Buffon judged that the useful ideas were drowned in many vague statements. A most remarkable technologist, Henri Duhamel du Monceau, took over the project, and he published a rearranged version of Tull's book under the title, *Traité de la Culture des Terres suivant les Princeps de M. Tull Anglais* in 6 volumes between +1753 and +1761. He followed them up with a two-volume work entitled *Elements d' Agriculture* in +1762. Duhamel's books were rendered into English by John Mills (+1759) and Philip Miller (+1764) respectively, and his translators succeeded in promoting Tull's ideas in England. Duhamel was also translated into Dutch (+1763 to +1765) and German (+1752), and Ubaldo Montelatici declared in +1753 that a new method of farming had been brought to light by M. Tull and that it had reached the Italian agronomes via Duhamel's work.[b] In sugar circles Duhamel probably exerted even greater influence as he published the first serious monograph on sugar refining *Art de Rafiner le Sucre* in +1764. We do not have any evidence of him directly promoting mould-board plough cultivation in the West Indies, on the contrary in the *Art* he described planting in holes without comment.[c]

Contemporaries expressed a surprising amount of interest in Tull's methods of cultivation and most educated people in Europe had heard of him. Earlier we related how the wits at Sir Joshua Reynolds' soirée reacted to James Grainger reading his poem on sugarcane, in which we find:[d]

> Might not the plough, that rolls on rapid wheels,
> Save more labour to the hoe-armed gang?

[a] Tull contended that the comminution of soil particles by ploughing, made nutrients available for crops, and claimed that this act rendered fertilisation unnecessary. Most of his followers quietly forgot about this injunction, but the controversy on this point undoubtedly inhibited the spread of Tull's ideas in England.

[b] Fussell (6), pp. 50–5 for Duhamels publications and translations.

[c] Duhamel du Monceau (2), p. 2. Duhamel's description obviously derived from Labat (1).

[d] Grainger (1), p. 484. See also p. 262, fn. e.

> Might not the culture taught to British hinds,
> By Ceres' son, unfailing crops secure;

Grainger proved himself more thoughtful than a number of modern poets, as he provided a footnote equating 'Ceres' son' with 'Jethro Tull Esq. the greatest improver in modern husbandry'. English, Flemish and French landed gentry expressed interest in Tull, and more especially in Tull's ideas as presented by Duhamel.[a] The discoverer of oxygen, Antoine Laurent Lavoisier, had an experimental farm researching all aspects of new agriculture. 'Other great landowners who established 'study' farms included Turbilly in Anjou, Duc de Bethune, Charort in Berri, Choiseul at Chanteloup, de la Rochefoucauld at Liancourt, de Monteyn at Brie'.[b] We have examined this detail to demonstrate that the new horse-hoeing husbandry was available in a mature form for transmission to all European colonies by +1760, and that it was widely known by persons of influence who could assure transmission. It is not surprising that the mould-board plough and horse husbandry surfaced with sugarcane culture in Spain by the mid +18th century, in Mexico on the Cortés plantations about +1770, with the Benedictine Fathers in Brazil about +1770,[c] and in the English colony of Antigua about +1750. Let us examine the Spanish and English situations in more detail.

In mid +18th-century Spain, Joseph-Antoine Valcarcel outlined a ridge and furrow system in which growers fashioned the rows with a double mould-board plough and cultivated the inter-rows with a plough, most probably a scratch plough. Inventories of the Cortés sugarcane plantation in Mexico indicated the advent of the 'Spanish' plough at this time as well as the practice of two *beneficios* (inter-row cultivations). The furrow system described was radically different, and more hydraulically efficient than the raised bed system with sub-surface irrigation described by the medieval Hispano-Arabic agronomists. It was also more labour efficient, and Ward Barrett has documented a fourfold increase in output of labour in his detailed study of the Cortés plantation from the +16th to the early +19th century. Barrett had no information on possible technological changes, and was at a loss to explain these large differences:[d]

> The change in amount of sugar produced per unit of labour was approximately fourfold in the period reviewed here. In an agriculture characterised by widespread application of scientific research, a change of such magnitude would be regarded as the near-equivalent of a revolution, a sign of progress and great improvement. Yet it seems unlikely that even those involved in the industry knew that it happened; this is the im-

[a] Duhamel had greater credibility because he believed in fertilisation. Tull asserted that fertilisation was not necessary, the horse hoeing liberated nutrients in the soil and the fine tilth allowed easy absorption.

[b] Fussell (1), pp. 149–50.

[c] Schwartz (2), p. 17. The information is limited to the fact that a large mould-board plough (*charrua*) was constructed and employed on the Engenho da Varge and ploughing performed on Engenho Camorim, both engenhos belonging to the Rio de Janeiro monastery.

[d] Barrett (1), p. 104.

plication of Ruiz de Valesco's characterization of the mode of production that held sway in the late +19th century in Morelos as Cortesian, and there is no sign in his work that he saw any difference between the sixteenth and nineteenth centuries in respect of productivity and efficiency.

Barrett quoted extensively from Ruiz de Valesco's work, but there is no reason to believe that Ruiz de Valesco had any real evidence on the subject. A change evidently took place in both Spain and Mexico, from the traditional Hispano-Arabic system of sugarcane planted in holes and irrigated sub-surface by block to sugarcane planted in rows, irrigated down the row and inter-rows kept free of weeds by ploughing.[a] The fourfold increase in labour efficiency in Mexico came in the same order of magnitude as given for Louisiana above. I consider that the new agriculture in Spain and Mexico formed part of the general movement to better cultivation stemming initially from the Dutch, and taken up by Jethro Tull. As stated earlier, we can discern a Chinese influence in plough construction and the concept of inter-row cultivation introduced through the auspices of the Dutch. I discount a direct introduction of sugarcane agricultural technology from Spanish experience in the Philippines and south China, because of its synchronisation with events in Europe, and Valcarcel's statement that he was influenced by English agriculture through French authors.[b] However, every op-

[a] One of the many strengths of Barrett's study is that he included a considerable amount of statistics. The following points clearly indicate a vast change in methods between the inventories of +1767 and the next available in +1777:

1 Until +1767 the number of operational ploughs varied around 20. In +1777 the number increased to 44 and by +1800 had stabilised to about 60–70. At the same time the number of oxen used for ploughing rose from about 100 in +1763 to about 400 in +1800 (pp. 44, 131, table 19).

2 The number and type of plough-shares changed in the same period. Until +1767 the plough-shares (*rejas*) in stock never numbered more than 21. In +1777 the plough-shares were changed to *rejas castellanos* Spanish shares, and numbered 97 (p. 44). By analogy to the European situation we have interpreted the Spanish shares as shares plus mould-boards for making furrows.

3 After +1767 the annual acreage planted rose from 250 to 350, thus increasing by about 100 acres, and ratoon crops were no longer grown. Planting and harvesting then became restricted to the dry season (p. 46, 48).

4 The inventories of one section. Altacomulco, at this time confirmed that cultivation consisted of two hand weedings and two *beneficios*. The *beneficios* were performed by plough, and 'consisted in the gradual reduction of the truncated ridges separating the furrows where the cane had been planted, moving the soil to form finally a ridge where the furrows had been' (p. 47). It appears that the mulattos performing the *beneficios* preferred task work to day labouring, and the faster mule to oxen (p. 104). The number of mules increased from 97 in +1753 to 400–500 in the +1790s (p. 131. table 19).

5 The secondary pressing of sugarcane bagasse in a beam press was discontinued during the +1750s (p. 55).

In +20th-century business management terminology, this mid +17th century change in operations in Mexico, with new technology introduced simultaneously in field and factory, would be classed as a bold and massive corporate reorganisation. In addition, labour relations were reorganised – the managers recognised the desire of labourers to work by task rather than day. This was a pivotal strategy in the successful Chinese-managed sugar plantations in Java. Work by task had two major effects on management; first, costs could be readily predicted and controlled; second, inter-locking tasks could be easily managed as it proved possible to see at a glance the progress of each section of the operation against scheduled output.

[b] Michaud (1), vol. 42, p. 426.

portunity existed from the mid +16th century for direct transmission to Spain and the New World from China and the Philippines via the Spanish.[a]

Let us now turn to the progress of the Chinese-type mould-board plough technology in the English colonies. The first exponent of the mould-board plough and horse-hoe cultivation in sugarcane agriculture appears to have been Colonel Samuel Martin of Antigua who began experimenting about +1750. Martin was born in Antigua in +1693, heir to the plantation Greencastle, and spent the first fifty-seven years of his life involved in Antiguan politics but resided in England for about half the time. He was forced to take up agriculture around +1750 to rehabilitate his mismanaged plantation. Martin was rightly looked upon as the founder of scientific plantation management, and his *An Essay Upon Plantership* became one of the classics of both sugarcane agriculture and plantation management literature; the first edition appeared about +1750 and the seventh in +1785.[b] Arthur Young republished it in +1792 in the *Annals of Agriculture* for 'hints of importance may be taken by British farmers, especially in the article of raising manure; there are other reasons for the insertion, which the intelligent reader will see'.[c] Amongst other things, Martin expounded in his essay the ways and means of adapting Jethro Tull's horse-hoeing husbandry to sugarcane agriculture. Martin exerted greater influence than a single book may suggest as he accepted young men as 'apprentices' and 'over the years, a substantial number of young Englishmen and Scotsmen received diplomas from the Martin school of plantership'.[d] Martin only recommended mould-board ploughing and inter-row cultivation with the Kentish horse hoe for loose, flat soils. On the majority of soils on hillsides he stuck with the traditional system of growing cane in holes. The Tullian horse-hoe husbandry spread slowly in Brazil and the Caribbean principally, because large areas of hillside were cultivated.[e] The Tullian methods proved more adaptable to the

[a] The Spanish employed the mould-board plough for making ridges and furrows, pit storage of seed cane, and a secondary press for crushing sugarcane bagasse which was akin to the Chinese rope-clutch press. In looking for a possible route of transmission from China, we cannot fail to note that there was every opportunity from the time the Spanish occupied the Philippines in +1564. I shall explain under (e) 'Cane sugar manufacture' below, how the Augustinian Martin de Rada went to the Philippines with the founding party in +1564, and immediately commenced collecting information on China, including books in the Chinese language which he had translated. In +1575 de Rada went on a mission to Fukien, the major contemporary sugar-producing area of China. He sent a report, books and papers to the court of Philip II. In short, continuous opportunities for the transmission of Chinese methods to Spain existed after +1564, and a transfer of Chinese agricultural techniques to Spain is certainly feasible.

[b] Martin (1). See Sheridan (1) for a life of Martin and editions of his *Essay*.

[c] Signed footnote on p. 236 of Martin (1). In addition it should be noted that the *Annals of Agriculture* carried numerous letters from Caribbean planters on sugarcane agriculture and was more than an English domestic journal.

[d] Sheridan (1), p. 138. Richard Sheridan (1) discussed Martin's career and achievement, especially from the point of view of a manager rather than a technologist.

[e] European plantation owners in Brazil and the Caribbean were very reluctant to adopt ploughs, scratch or mould-board, for land preparation, let alone for sophisticated inter-row techniques. Sugarcane was planted in holes or trenches in land prepared by negroes with hoes. This reluctance has been attributed to the institution of slavery, the hypothesis being that the availability of slave labour did away with the need to improve technology, see Green (1), p. 52 and Goveia (1), p. 129. I will not enter into this debate except to comment on soil

(*cont.*)

flatter soils of Jamaica, and Edward Long promoted the mould-board plough in his *The History of Jamaica* of +1774.[a] Yet, it is +1793 before we find the horse hoe mentioned in Bryan Edwards' *The History, Civil and Commercial, of the British Colonies in the West Indies*.[b] The controversy over mould-board ploughing and horse hoeing still raged as late as +1845, when W. F. Whitehouse commenced writing his letters to the Jamaican *Royal Gazette* and *Jamaican Standard* under the pseudonym, Agricola.[c] In all these communications we see the horse hoe as a separate implement, the possibility of the mould-board plough as a horse hoe did not surface until about 1820 in Louisiana.[d] The essential difference between the two instruments was as follows. The mould-board made a deep cut alongside the row, throwing soil into the inter-row, and this soil could then be worked up with scarifiers and moved back; alternatively, it could be used to reshape the field for irrigating down the inter-row rather than down the row. The objective with the horse hoe was to cut the weeds off two inches below the surface and restore tilth, but not to move soil.[e]

Around +1775 a development occurred outside the sugarcane area. Francis Forbes, another disciple of Jethro Tull, began issuing a series of widely read publications supporting Tull's ideas on planting crops in rows and inter-row cultivation. Forbes, in his *The Modern Improvements in Agriculture containing the Principles of Tillage and Vegetation* of +1784, recommended the small swing plough variously known as the Rotherham, the Dutch plough and the patent plough,

Footnotes to page 272 (*cont.*)

types and plough design, ignoring undoubted factors such as the conservatism, insensitivity and inhumanity of vast numbers of planters. First, large amounts of land in the Caribbean and Brazil were so steep that it proved impossible to plough with the heavy-wheeled plough pulled by several animals. This only became possible at the end of the +18th century when the light swing plough with a curved iron, mould-board that could be pulled with one or two animals, became available. It is difficult for man and beast to plough across the slope on steep land as human operators find it hard to balance themselves on the incline. The problem with the mould-board plough is that it throws the furrow-slice onto one side and, if the operator wishes continually to throw a furrow-slice up the hill, the plough must be dragged back across the field to make the next furrow. For this reason in vol. 6, pt 2, p. 104 Francesca Bray stated that the Chinese used the scratch plough on hillsides, and this undoubtedly led in China to the construction of flat terraces on which the mould-board plough could be employed. Second, animals could not haul the existing plough economically on flat land such as the *massapé* in Brazil where the soil was stiff. Samuel Martin of Antigua put the position in forceful terms (Martin (1), p. 266): 'Deep and loose soils may be ploughed with a small strength of cattle or mules, but stiff lands, in this hot climate, require more strength of cattle than we are able to maintain in our small pastures; for if those strong soils are either too wet, or too dry (as is generally the case), ploughing is impractical.' These lands had to await better plough designs based on the curved iron mould-board that became available in the early +19th century. As well as giving difficulty in ploughing, planters had suggested that under the usual tenuous moisture relations, planting in rows without mulching on hillsides would lead to serious loss of moisture and lower yields. Experience in 20th-century Barbados has confirmed their contentions, see Hudson (1).

[a] Watts (1), p. 430.

[b] Edwards (1), vol. 2, p. 216.

[c] Collected in Whitehouse (1).

[d] As was mentioned on pp. 270–1, a scratch-type plough appeared to have been used in Spain and Mexico for inter-row cultivation.

[e] Jethro Tull thought that by producing a fine tilth, nutrients were made available and that it was not necessary to fertilise plants. This more than any other factor delayed the wide introduction of his method in England. Samuel Martin did not subscribe to this part of the Tullian philosophy and was a strong advocate of fertilisation. Some horse hoes were designed to be adjusted to throw soil on to the rows in the final cultivation.

as 'the instrument proper for horse-hoeing'.[a] Gordon Fussell, our authority, commented on Forbes and the Rotherham plough as a horse hoe: 'it seems likely that any farmer that read his book and became a Tullian cultivator would not have been slow to adopt it'. I agree with Fussell that it was logically an inevitable development *once a lightweight mould-board swing plough became available.* The Rotherham plough developed in England about +1730 from a Dutch model, for which a Chinese influence was suggested in Vol. 6, pt 2; I further postulated above that a Chinese model derived from sugarcane in Java could have stimulated inter-row horse hoeing. It would be trite to suggest a direct line of Chinese influence on Francis Forbes' mould-board inter-row cultivation. However, shortly later a more direct Chinese influence appeared in the sphere of sugarcane cultivation. In +1789, Henry Botham gave evidence before The Committee of the Privy Council hearing evidence on the slave trade.[b] I have cited above (pp. 228ff) Botham's description of how the Chinese used ploughs for inter-row cultivation in Java. Botham achieved some notoriety because he advocated the idea that Chinese techniques employing free labour attained greater efficiency than slave-driven labour in the Caribbean. Botham's submission exercised a continuing influence as it was republished in the *East India Papers on the Sugar Industry* of 1822, and in 1831 George Richardson Porter gave a favourable summary of Botham's submission in his widely read *The Nature and Properties of the Sugarcane; With Practical Directions for the Improvement of its Culture and the Manufacture of Its Products*, as did W. F. Whitehouse in his *Agricola's Letters and Essays on Sugar Farming in Jamaica* of 1845. The mould-board plough hoe system was finally adopted in Louisiana early in the 19th century initially amongst the Anglo-Americans.[c] Several factors contributed to its adoption. First, the land in Louisiana proved ideal with long flat fields suitable for

[a] Fussell (6), p. 96.

[b] East India Company, (1), pp. 83–5.

[c] Sitterson ((1), p. 128) showed that the plough system commenced amongst the Anglo-Americans, and this is consistent with the data presented above. For the record, I considered but discarded alternative scenarios based on an introduction from the French colony of St. Domingue, the modern Haiti, in the second half of the +18th century. It is clear from Sitterson (1) that the Louisiana sugar industry received a considerable number of technological inputs by transfer from St. Domingue; the principal agency being French sugar makers who fled with the great slave uprising of +1791 that destroyed the large French industry of St. Domingue, see Sitterson (1), pp. 3–12. There were some ploughs in St. Domingue, but it is not clear whether they were ever applied for inter-row cultivation, see Tussac (1), p. 163. The first scenario centred around the fact that Jethro Tull conceived the horse-hoe husbandry through watching farmers in Languedoc in the south of France, cultivating between rows of grapes with the common ard plough. Louis Dermigny indicated an intimate relationship between Languedoc and the French colony of St. Domingue (Dermigny (3)). St. Domingue exported sugar to Languedoc for refining, and in return received goods and immigrants from Languedoc. These immigrants could have transferred inter-row cultivation techniques direct from source. The second scenario was that there were at least three large plantations connected with the French nobility that would most probably have heard of the new husbandry and may have practised it, see Watts (2), p. 351. For the third scenario see under (*e*), below, where I shall draw attention to the intelligence system of the Jesuit order that collected information concerning sugar making on a world-wide basis, and disseminated new technology and management techniques through a secretariat in Rome. The Jesuits had their largest operation in St. Domingue, and sent the first sugarcane from there to their Louisiana operations in +1733 and finally established it in +1754, see Sitterson (1), p. 6. The Jesuits had every opportunity to transmit any technology available.

ploughing, and planters were beset by the problem of a shortage of slave labour. Second, the English inputs described earlier stimulated indigenous experimentation. In +1788 Thomas Jefferson invented an improved light-weight plough which he claimed to be the first designed on mathematical principles, even asserting priority for this invention in England and France.[a] In 1814 Jethro Wood patented a scientifically designed iron mould-board plough, and followed it up in 1819 with a model replete with standardised replaceable parts. This plough achieved great success in New England.[b] The mould-board plough was the major agricultural implement in use in the early United States; in frontier situations single all-purpose equipment proved essential, separate horse hoes would have been a luxury. The mould-board plough system was perfected for sugarcane in Louisiana, and remained supreme until 1905 when the disc cultivator captured the market.[c] From the Louisiana centre the Chinese mould-board plough systems probably diffused to Natal and Australia via Jamaica. Fiji derived its systems from Australia, and at the present time the Indian cultivators of Fiji are the best exponents of the methods that originated in China in the late +16th century.

We will finally examine ridge and furrow systems employed around the world in sugarcane agriculture. The Chinese method has certain priority as it was clearly described for sugarcane in the *Thang Shuang Pu* of c. +1154. This system consisted of the general Chinese agricultural strategy of ridges and furrows (*mu chhüan*) that dated back to the *Lü Shih Chhun Chhiu* of the −3rd century. The only reason for examining this system on a world basis is the marked similarity between the ancient Chinese system and fields in other countries such as modern Turkey (see Figs. 44, 45). There is no evidence of ridge and furrow, apart from China, until the +16th century in Brazil where it appeared under the name of trenching. The Portuguese may have observed sugarcane grown by this technique in China, and introduced it. Alternatively, it may have been developed on Madeira so that irrigation water could be run down the furrows on the narrow terraces. These hypotheses remain within the realms of pure speculation and are only suggested for future testing. Trenching by hand continued in Brazil and the Caribbean until the mould-board plough technology superseded it in the +19th century where appropriate. The Cuban, Don Alvaro Reynoso, detailed his trench and ridge method in his *Ensayo sobre el Cultivo de la Caña de Azúcar* of +1862. Considerable mystique surrounds the Reynoso system, but it is merely a ridge and furrow system in which the furrows were dug out by spades in a box-like drain to a depth of about two feet and the soil piled on the inter-rows to form ridges. Although there were a considerable number of Chinese field labourers in Cuba when Reynoso developed his system, I believe

[a] There was a certain amount of Anglo-American rivalry concerning the invention of the light curved iron mould-board plough, see Fussell (2), pp. 45–6, and Partridge (1), p. 53.

[b] Partridge (1), p. 53.

[c] Sitterson (1), p. 278.

it was merely an elegant form of the old New World trench system with deeper furrows. The Reynoso system failed to be adopted in Cuba and it would have quietly faded away, if it had not found enthusiasts in the Dutch who translated Reynoso, and implemented his methods in Java. The Reynoso system attained success in Java because it proved eminently suitable for rotating paddy rice with sugarcane. A Dutch agronomist, van Dillewijn, even popularised it in 20th-century Egypt and Turkey. The ridge and furrow system has been recorded in areas of Chinese influence, Taiwan and the Philippines, in the 19th century and continues in China in appropriate situations today.

(*e*) CANE SUGAR MANUFACTURE

(1) INTRODUCTION

Numerous names appear for cane sugar manufactured in all parts of the pre-modern world, and it has often proved difficult, if not impossible from the scanty information available, to identify the types of sugar to which they referred. To avoid getting muddled with contemporary terminology, I present the following simple concept of sugar as a base for understanding the historical evolution of sugar manufacture: sugar contains sucrose and impurities, and it is the ratio of sucrose to impurities that determines the type of sugars made. Differences in this ratio resulted in a great variety of sugars, each with its own appellation. Most consumers in the pre-modern world preferred sugar with a high level of impurities, probably because of the flavour they imparted. But the Western European fixation for sugars with a high level of sucrose and a low level of impurities has gradually eroded these traditional preferences. Industrialisation, imperialism and the adoption of Euro-American culinary habits the world over have changed, and still are changing people in Africa and Asia into consumers of impurity free 'tasteless' sucrose.[a]

Sugarcane has a fibrous structure containing juice, an aqueous solution of sucrose plus impurities. The impurities are usually classified as:

1 *reducing sugars* (principally glucose and fructose), named because of their property of reducing alkaline copper sulphate to copper oxide
2 *ash*, inorganic salts, principally of potassium and calcium
3 *other organic matter*, gums, colloids, protein, starch, colouring matter.

Broadly speaking, from the historical point of view two types of sugar products were manufactured by manipulating the sucrose/impurity ratio of cane juice. I

[a] For an exposition of the concept of sugar see Daniels (*4*), pp. 80–3. For the role of industrialisation in promoting consumption of high sucrose, impurity-free, tasteless sugars see Mintz (1).

classify the first type as unrefined sugar products which contain high levels of impurities. Early humans consumed sucrose and impurities together by chewing sugarcane, drinking expressed juice and high-density syrups, and eating crude sugars such as *gur* of India, produced by simple dehydration through boiling, but made few attempts to remove most of the impurities. I call the second type refined sugar products, a term which includes sugars that have undergone processing to separate all or some of the impurities.[a] The second type only appeared after humans acquired extractive, clarifying, boiling and crystallisation and draining techniques for removing impurities.

(2) Unrefined Sugar Products

(i) *Sugarcane stalks*

Sugarcane, the raw material of sugar making, also served as a food in its own right, and accounted for 10 per cent of the normal diet in some regions, such as India and the New Guinea highlands.[b] The inhabitants of most areas of south China ate sugarcane as a fruit and regarded it as a very desirable snack. In the Western world sugar continues to be looked upon as deleterious. The rational arguments against it rest mainly on the association of dental caries with a high sugar diet, but a large number of studies have been based on subjective and dubious data.[c] The solution to this paradox is that sugarcane in its raw state contains calcium sucrose phosphates, and research has shown that these chemicals harden dental enamel and reduce dental caries; unfortunately conventional sugar refining eliminates calcium sucrose phosphates.[d] These same refining procedures remove several classes of protein which Japanese researchers have shown to have potentially beneficial effects on blood pressure.[e] These considerations have tended to hide the important role that sucrose, as the cheapest known source of calories, can play in the diet of undernourished people. Unrefined sugar products are highly desirable food in developing countries, principally because they supply a sufficient quantity of calories to prevent meagre protein intakes from being burnt up as energy.[f]

[a] For details on impurities in sugarcane see Honig (1), vol. 1. Literature before 1900 usually referred to reducing sugars as glucose or uncrystallisable sugars.

[b] Waddell (1), p. 124.

[c] As an example of this type of argument see Duffy (1) which has an extensive bibliography; and Mechling & Mechling (1) for a more balanced exposition.

[d] Curtin, Gagolski and Smythe (1), p. 509.

[e] Kimura, Okuda and Arichi (1) have shown from experiments with mice that the non-sugar fraction of black sugar has possible therapeutic effects in man for inhibition of serum triglyceride, lipid peroxides and insulin.

[f] Alias (1). See Marstrand and Rush (1), pp. 81–2 for a discussion of human body metabolism burning up protein, when caloric intake is too low.

(ii) *Juice* (chê chiang)[1]

Juice can be readily extracted from sugarcane by unsophisticated instruments such as the mortar and pestle, which were probably known early in the history of the crop, as they have been found in south Chinese archaeological sites.[a] Sugarcane juice was part of the culture complex that spread out into the Pacific; for example, the Fijians used it in puddings, and the Hawaiians as love potions.[b] It is still consumed in Taiwan and in major cities in south China today where side-walk vendors cruch sugarcane on the spot for patrons. The Buddhist *Tripitaka* carried many references to sugarcane juice, as it formed one of the principal eight juices (later increased to fourteen), permitted by the Buddha. Sugar constituted the major energy component of all juices regardless of the type of plant, and we have detailed the fourteen juices and their botanical derivation in Table 7 along with references to the appropriate authorities. When the principal juices were offered to the Buddha, he decreed that they should be consumed at the prescribed hours, and also in the afternoon;[c] this allowed monks to drink juices at all times during daylight hours, and so they constituted an important component of their diets. The introduction of Buddhism into China must have encouraged Chinese converts to drink sugarcane juice, a beverage that they must already have known from contact with the ethnic people of south China and north Vietnam.

(iii) *Syrup* (chê chiang[1])

Expressed juice was readily evaporated in earthenware pots, and when concentrated to above 70 per cent solids formed a very stable product, as pathogens do not grow in heavy syrup because of the high osmotic pressure. Since it can be readily stored in jars and hollowed bamboo containers, syrup proved a viable alternative to unprocessed sugars which were not stable and readily deliquesced. Pottery boasted a great antiquity in south China being one of the arts of the Yüeh and preceding cultures.[d]

Syrup, the first sugar product known in the world, appeared as early as −500 in India in the Buddhist *Prātimok'sa* under the Sanskrit name *phāṇita*.[e] *Phāṇita* was one of the five medicines allowed to Buddhist monks when sick.[f] It assumed importance with laymen as a food, and as late as +500 the armies of

[a] Vol. 4, pt 2, p. 183.
[b] Seemann (1), p. 321; Degener (1), p. 58.
[c] Maku (1), pp. 186–8. It should also be noted that the juice was 100 percent, i.e. undiluted.
[d] Meacham (3), pp. 160–1.
[e] Rhys Davids & Oldenberg (1), p. 27.
[f] The five medicines included ghee, fresh butter, oil, honey and cane syrup (*phāṇita*), see Horner (1), vol. 2, pp. 130–2.

[1] 蔗漿

the Indian King Harsha utilised syrup as a source of energy.[a] The Chinese also knew of sugarcane syrups quite early in pre-Buddhist times, and the first literary reference to them occurred in a poem entitled the *Chao Hun*[1] or the Summons of the Soul of −241.[b] However, the Chinese character *chiang*[2], translated as syrup, can also mean juice, which could equally well have been applied as a condiment in cooking. In the Buddhist texts translated in the first six centuries of our era, we find *phāṇita*, or syrup rendered into Chinese as *kan chê chih chiang*[3], *kan chê chiang*[4], *hei shih-mi chiang*[5], *shih-mi*[6].[c] The *Sui Shu*[7] (History of the Sui Dynasty) listed the term *pan-mi*[8] (literally half honey), probably a transliteration of *phāṇita*, as a product of Persia (*Pho-Ssu*[9]) and *Tshao Kuo*[10].[d] This wide array of terms can be regarded as arising from lack of fixed translation terminology rather than indicating any differences in quality. Sugar syrups had a continuing place in Chinese cooking from the Han dynasty onward.[e]

(iv) *Amorphous (concrete)*[f] *and massecuite sugars*

By boiling syrup and allowing it to crystallise a great range of products were possible. At one end of the spectrum the sugar mass was called amorphous because the crystal structure was not obvious. This product grades into massecuites which has varying amounts of crystal and syrup included around the crystal.

In early technologies syrup was allowed to dry in the sun and solidify into a concrete amorphous mix of sugar and syrup, known to the Chinese as *shih-mi*.[g] We have seen earlier that the Han Chinese first learnt of sugarcane and sugar as they moved south into the land of the *Pai Yüeh*[11] or hundred Yüeh, and later expanded their knowledge through contact with Indian Buddhism. Though the Chinese had their own set of terminology for soft and hard malt sugar, *i*[12] and *hsing*[13], they first knew cane sugar by the term, *shih-mi*, five *hu*[14] (approx. 518 litres) of which the King of Nan Yüeh[15] reportedly presented as tribute to Em-

[a] *Harṣacarita* (ed J Vidyasagar) through Gopal (1), p. 63.

[b] Tr. Liu, Wu-chi (1), p. 30.

[c] The Chinese rendition of the *Ekottarāgama sutra* made between +384 and +385 has *kan chê chih chiang*, see Taishō no. 125 (Nanjio no. 543) p. 705/1; the +416 translation of the *Mahāsāmghika Vinaya* has *kan chê chang*, see Taishō no. 1425 (Nanjio no. 1119) p. 362/2; and *hei shih mi chiang* appears in the Taishō no. 156 (Nanjio no. 431) p. 131/3 dating from +25 to +220 as one of the syrups allowed to monks. For evidence concerning the translation of *phāṇita* as *shih-mi* see Chi (1), p. 133 and Chi (3), p. 26

[d] *Sui shu*, p. 1857.

[e] Yu, Ying-Shih (1), pp. 57 and 67.

[f] True amorphous sugar is obtained by melting crystalline sugar and allowing it to solidify into an amorphous mass.

[g] This type of sugar was known as *gur* or jaggery in India, *banque* or *rapodura* in Brazil or *panela* or *chancaca* elsewhere in South America. As would be expected, the consistency varied from a heavy sticky mixture of crystals surrounded by syrup to concrete of hard microscopic crystalline sugar in syrup.

[1] 招魂 [2] 漿 [3] 甘蔗之漿 [4] 甘蔗漿 [5] 黑石蜜漿
[6] 石蜜 [7] 隋書 [8] 半蜜 [9] 波斯 [10] 漕國
[11] 百越 [12] 飴 [13] 餳 [14] 斛 [15] 南越

peror Kao-Tsu[1] (−206 to −195) of the Han.[a] The *I Wu Chih*[2] of c. +90 by Yang Fu[3] provided the first account for how it was made:[b]

If pressed the juice obtained [from sugarcane] can be made into a substance like soft malt sugar (*i*) and hard malt sugar (*hsing*). It is called *thang*[4], and is even more valuable. It can also be boiled and dried in the sun. Once solidified it becomes like ice. When broken its glossy surface is like a lapus lazuli chessman. Once eaten it immediately dissolves in the mouth. People of the present day call it *shih-mi*.

Here *shih-mi* referred to a concrete sugar, that is, an amorphous type sugar produced by simply boiling up cane juice to 'dryness' and sun drying it. During the Han dynasty the Chinese recorded *shih-mi* as a product of India, and also employed it in contemporary translations of Indian Buddhist texts.[c]

These types of sugars continue to be made around the world in the 20th century with only minimum attempts to remove impurities by skimming during boiling. Their enduring popularity derives from consumer appreciation of the flavour of the impurities contained in them. *Panela* in South America, *gur* and jaggery in South and South-East Asia still remain the preferred sugars of the common people. This was a very efficient method of sugar consumption as no sugar was lost in molasses, which was not separated, and the whole constituted a highly nutritious food which Japanese researchers have shown to have useful physiological effects. Its importance cannot be underestimated as in some areas such as western Colombia, it provided 25 per cent by weight of the effective diet.[d] This type of sugar is still made today in modern China, where south of the ranges operators boil sugar syrup with rudimentary skimming, and at crystallisation point pour it onto plaited bamboo mats in a layer about 1 cm thick with or without dividers. After the sugar crystallises and hardens, operators break the mass up into pieces, or slabs about 3 cm × 10 cm in size, and market it in this state.[e] A 19th-century gazetteer for Shao-Chou prefecture[5] in Kuang-Tung described the manufacturing process.[f]

Brown sugar (*hung-thang*[6]): The juice of *mao che*[7] [*Saccharum sinense*] is extracted, boiled and poured into a straw mat to coagulate. It congeals within the grids and forms pieces (*ning-chieh chieh chheng phiên*[8]). It is also called piece sugar (*phiên thang*[9]) and is eaten in the form of biscuits (*ping*[10]) made by mixing it with rice flour (*mi mien fên*[11]).

[a] *Hsi Ching Tsa Chi*, ch. 4, p. 3a. It should be noted that this source was not contemporary with Han Kao-Tsu.

[b] Quoted in *CMYS* 92.25.3. The *NFTMC* of +302 also has a similar description of *shih-mi* making in *Chiao-Chih*, which was located in present-day North Vietnam.

[c] For India see *Hou Han Shu*, ch. 88, p. 2921, and for an example in a Buddhist text see the *A Na Lü Pa Nien Ching* Taishō no. 46. (Nanjio no. 563) p. 836/1 which was translated in +185.

[d] Parsons (1), p. 119.

[e] Hirschmüller and Delavier (1), p. 523. Yamane (1), pp. 498–9 also furnishes an analysis of sucrose by polarisation 82.8%, reducing sugars 10.3%, ash 0.5%, moisture 2.5%.

[f] 1874 *Shao-Chou FC*, ch. 11, p. 29a.

[1] 高祖 [2] 異物志 [3] 楊孚 [4] 糖 [5] 韶州府
[6] 紅糖 [7] 茅蔗 [8] 凝結界成片 [9] 片糖 [10] 餅
[11] 米麵粉



Fig. 55*a*. Massecuite is poured into moulds and allowed to set in 20th-century Brazil. It is then cut or broken into pieces which are sold. This product is known as *panella* in South America, *phiên-thang*[1] in China and is common in Asia; Hemming (1), fig. 17.

Similar slabs of sugar remain a major product for local consumption in South America (see Figs. 55*a*, 55*b* and 55*c*), and it is most likely that the process is of Indian or Chinese origin via the Portuguese.

This technology appears to be a Pan-Asian phenomenon. It, and a variant where the syrup was poured into half coconuts, have been recorded as of indigenous methods in south India, Burma, the Shan States, Vietnam and south China.[a] We also find similar agricultural techniques distributed over a wide area in Asia with the sugarcane planted in holes or on moulds depending on drainage in four to six feet squares,[b] which leads us to hypothesise a Pan-Asian sugar technology, probably dating roughly from the +1st century.

(3) Refined Sugar Products: Introduction

Amorphous sugars and syrups retained impurities which consumers regarded as part of the food. However, solid sugars made by these methods suffered a serious disadvantage in that they remained hygroscopic and deliquesced in humid

[a] For south India, Burma, the Shan States see Watt (1), vol. 6, pt 2, pp. 225, 241 and 249; for Vietnam see Yamane (1), p. 498.

[b] For south China see Roxburgh (1), vol. 3, p. 27; for Vietnam see Poivre (1), p. 107; for Madras see Watt (1), vol. 6, pt 2, p. 233.

[1] 片糖



Fig. 55*b*. Workers vigorously stirring boiled syrup on a plaited bamboo mat with wooden paddles to make slab sugar at the Hu-Khou village sugar mill[1], Pan-Chung Shê-Tsu Hsiang[2], Fu-An City[3], Fukien, December 1990. This beating action on the syrup, which is supersaturated, causes the growth of a very fine-grained sugar. After cooling, squares are marked out with a two-pronged fork on the surface of the sugar, and then the whole block is broken up into slabs. In Fu-An city, *hung pan-thang*[4], literally, red slab sugar, is the local name for this type of sugar. The mat, plaited from *mao-chu*[5] (*Phyllostachys pubencens* Mazel ex Houz. de Leh), measured 373 cm (length) by 242 cm (width), and the syrup, which has been poured across the width of it, was 190 cm by 106 cm; orig. photo Christian Daniels.



Fig. 55*c*. Breaking slab squares on a mat at the same sugar mill as in Fig. 55*b*. The man squatting on the left inserts a pole under the mat along the longitudinal lines marked on the sugar block, while the two men on the mat snap one line of squares at a time, using the pole as a lever; orig. photo Christian Daniels.

[1] 湖口村糖樓 [2] 坂中畲族鄉 [3] 福安市 [4] 紅板糖 [5] 毛竹

Table 13. *Impurities in sugarcane and processes for their separation*

Impurity separated	Process	
Fibre	Juice extraction	(i) crushing (ii) crushing and pressing (iii) water washing and diffusion
Heat coagulable organic matter (colloids, gums etc.), suspended solids	Defecation by clarification	(i) temperature (ii) additives
Water in juice	Evaporation	
Dissolved salts and organic compounds	Crystallisation and drainage	
Water in sugar	Drying	

tropical climates to become an unattractive liquid mess. Historically the earliest major incentive for refining was to ensure a stable product that could be stored or transported over distance. I use refining in the same sense as Charles Davis who defined it as the process of separating impurities from raw sucrose solutions into different product streams.[a] With amorphous sugar there was only one product stream as all the impurities remain in the sugar consumed. If a refining process was initiated and syrup drained from amorphous sugar, some of the impurities were separated into molasses, another consumer product. In effect, impurities are not eliminated or discarded, but merely redirected for other uses, such as making alcohol. This concept was an improvement over the conventional one, which viewed the goal of refining as the simple concentration of sucrose, because it described the actual operation more accurately.[b] Impurities and the processes involved in their separation are given in Table 13 and discussed below. Pre-modern sugar makers in Asia manufactured a range of sugar products with impurities reduced to levels that ensured relative stability thereby preventing deliquescence, but retaining most of the desirable taste. This principle of refining has been practised in Asia until the present day, and these sugars with varying levels of impurities remain the backbone of indigenous consumer markets.[c] This contrasts with the modern West where the objective of refining has been to obtain a pure white sucrose devoid of impurities; in other words, a taste-free sweetener. In modern times refiners in Asia, the Dutch in Java, the British in India and Hong Kong as well as the Japanese at home and on Taiwan have striven to expand the market for impurity-free sugars; the promo-

[a] Davis (1).

[b] Deerr ((1), pp. 92 and 449) has an even narrower view of refining. He calls it the process of concentrating sucrose by recrystallisation and does not include processes such as clarification and drainage of syrup from massecuite. He places the first reference to refining with al Nuwairī in Egypt.

[c] Yamane (1).

tion and adoption of Western eating and drinking habits has greatly facilitated their purposes.

(i) *Juice extraction (separation of juice from fibre)*

South of the ranges

In the previous section on agriculture we noticed considerable differences in techniques north and south of the ranges. The same consideration applies to manufacture, and we can speculate that the south probably employed indigenous methods until the +16th century. I have detected four major methods of juice extraction prior to the adoption of roller milling, which first appeared in China during the late +16th and early +17th century in Chiang-Hsi and Fukien.

First was the mortar and pestle, one of the earliest methods of food preparation, the use of which extended throughout the ancient world.[a] It was very effective along with hand squeezing for processing small quantities of sugarcane. It also proved a most effective method if combined with washing and diffusion in boiling water.

Second was a flexible pole sugarcane crusher. This machine effected crushing by bouncing a flexible pole on sugarcane held on a hard surface. Examples from South-East Asia show differences in the methods of activating the pole and the nature of the hard surface, but in all cases the generic technology was the same: French explorers in Laos during the 1920s photographed a machine which pounded sugarcane in a vertical tree fork utilising power exerted by children jumping up and down on a log hammer; the juice flowed into a container below. The weight of the log hammer was balanced by tying it to the limb of a tree.[b] A similar type of machine has been observed in the Philippines,[c] a country for which other types of pole presses, such as one activated by flexing the pole with a flat rope, have also been documented (see Fig. 56).[d] The antiquity of these machines is not known, but we must consider the possibility of them having been employed in south China during ancient times.

Third, sugarcane was hammered in a mortar with a trip hammer (see Fig. 57), which could be activated by humans, animals and water power. Since it served as standard equipment for dehusking rice, and as it has been described for sugarcane processing north of the ranges,[e] we hypothesise that it was also applied south of the ranges. The resulting mash may have been boiled in water or squeezed in a press.

[a] Vol. 4, pt 2, p. 183.
[b] Sarraut (1), p. 357.
[c] Hines (2), p. 302.
[d] For an illustration of the *opa't* sugarcane press see *University of Manila Journal of East Asiatic Studies*, vol. IV, no. 4. (Oct. 1955), p. 27.
[e] For use in dehusking rice see Vol. 4, pt 2, p. 52 and for sugarcane crushing see *NSCY*, ch. 6, p. 14a.

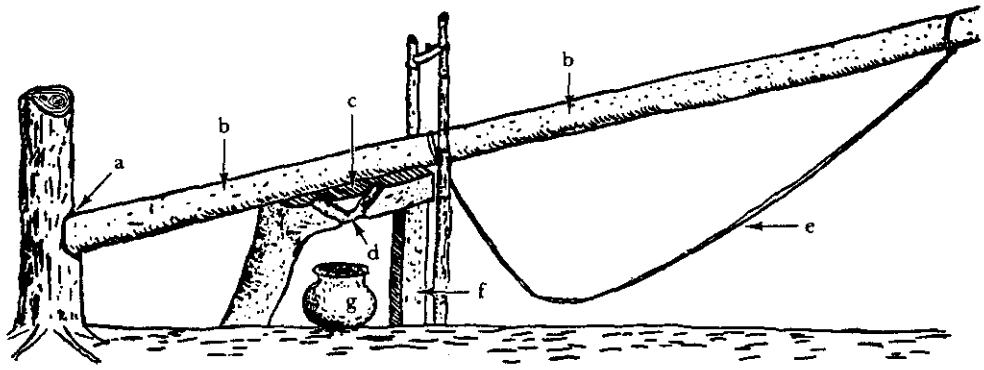


Fig. 56. The *-opa'l* sugarcane press used in the Philippines, redrawn from an illustration in *University of Manila Journal of East Asiatic Studies*, vol. IV, no. 4 (Oct. 1955), p. 27. Sugarcane was placed on (c) the press table, and pounded by treading on (e) rattan string. The key reads as follows: (a) *hu'gu*, hole in the tree for the press pole. (b) *-opala'n*, press pole. (c) *chama'gan*, press table. (d) *tadja'an*, cavity in the *chama'gan* through which the extracted juice flows to the earthenware jar below. (e) *liyu'chan*, rattan string to make the *-opala'n* move up and down, by means of the foot of the operator. (f) *tun'lan*, post sustaining the *chama'gan*. (g) *chaladja'n*, earthenware jar.

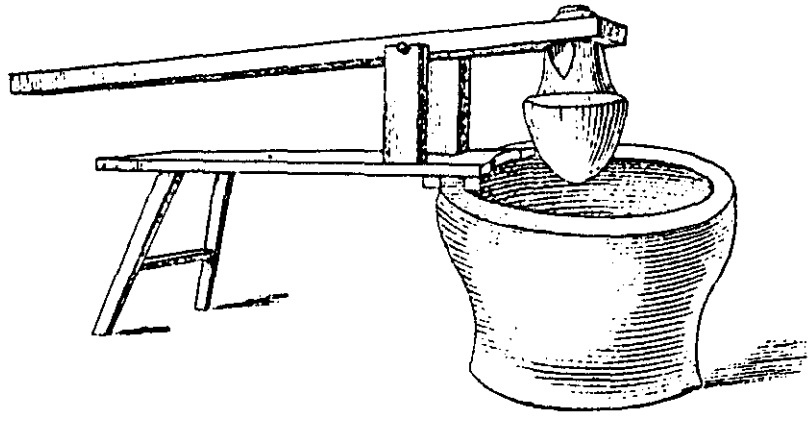


Fig. 57. A hammer mill from 19th-century China. Sugarcane was mashed in this type of machine until the +16th century, see West (1), pl. 1.

Fourth, at some date yet to be defined, but probably beginning with the advent of the commodity production of sugar south of the ranges during the early Sung, a large heavy wooden roller was employed to mash up sugarcane laid on a wooden board staging; the roller was cambered and drawn by humans or animals. This type of mill, known as the *khun nien*[1] in Chinese, was the generic term for a horizontal roller travelling around a circular course drawn by animal power. It was first described and illustrated in Wang Chên's *Nung Shu*[2] of

[1] 輥輾 [2] 農書



Fig. 58. The *frangourinier* was operated by moving a horizontal roller over sugarcane in a straight path. This is a Mauritian postage stamp commemorating the *frangourinier* which was used widely in the +18th century. See Coombes (1), opposite p. 114 for a scale drawing.

+1313,[a] but not documented for crushing sugarcane until the +18th century when Charles Gustavus Eckeberg, the captain of a Swedish East India Company ship, recorded it near Kuang-Chou in his *A Short Account of the Chinese Husbandry*.[b]

Some sampane cargoes of canes are brought together to a convenient place on the river side; there they build a hut of bamboo and mats, at one end of which they make a furnace with two great iron-boilers; and at the other an even floor of a considerable size laid with planks, over which two oxen draw an angulated roller of hard wood. The canes, which are disposed in layers under the roller, are crushed; and the juice, which by means of a canal is conducted to the end of the floor, is there collected in a great vessel. The remaining juice in the canes is entirely boiled out in one of the boilers, is mixed with the expressed juice, both are strained through a cloth, and boiled into a brown sugar in the other boiler: the leaves and stalks serve as fewel.

I surmise that the Chinese utilised this type of mill for crushing sugarcane from quite early. I shall refer to this machine by its French name, the *frangourinier* (see Fig. 58) to avoid confusion with the edge-runner or roller mill.[c]

[a] *WCNS*, p. 284.
[b] Osbeck (1), vol. 1, p. 297.
[c] The *frangourinier* was used in Mauritius from the early +18th to 19th centuries, see Coombes (1), p. 114 and plate.

As Eckeberg noted, the juice from the *frangourinier* was collected underneath the staging, and the refuse then diffused in boiling water. The extracts were mixed at an appropriate time, boiled and crystallised. This probably served as a most efficient method for separating fibre, and diffusion installations in India continuously achieved about 90 per cent juice extraction, while roller milling only registered roughly a maximum of 65 per cent in the pre-19th-century period. We shall examine these rates of efficiency further below in a discussion on the development of roller milling north of the ranges. It is thought that roller milling moved south of the ranges during the +17th century, only gradually replacing the more efficient *frangourinier* when deforestation reduced the large fuel supply necessary to boil off water added in the diffusion and washing process. Deerr mentioned the *frangourinier* in Mauritius during the mid +18th century and attributed the invention to Egypt without any documentation.[a] I believe that this invention was almost certainly Chinese, because the generic technology appeared in the *Nung Shu* of +1313. Opportunities existed for a transfer from China as the French maintained frequent contact between Mauritius and Canton during the +18th century, the former being a port of call for French ships travelling to East Asia. Charles de Constant related how in +1784 he recruited a dozen labourers and Chinese sugar technicians at Canton for work in Mauritius, and how they were lost at sea with their equipment before arriving.[b] According to Coombes the *frangourinier* appeared in Mauritius after the Dutch left in +1710.[c] I hypothesise that a previous consignment of Chinese technicians may have introduced this equipment. Alternatively Pierre Poivre, the prominent French physiocrat, who visited Mauritius, Indo-China and China during the +1740s may have introduced the concept. Nevertheless there were differences between the Chinese and Mauritian machines. The surviving Mauritian equipment possessed a roller that travelled backward and forward across the sugarcane, while in China and Indochina the roller moved in a circular fashion.[d]

We can conclude that south of the ranges, sugarcane crushing commenced with simple pounding and pressing techniques. Later sugar makers improved the efficiency of these methods by boiling the pulped cane in water, and this remained the principal method until the introduction of the roller mill during the +17th century.

North of the ranges

Recent research has suggested that some sugar products were produced north of the ranges by the −2nd century. Archaeological excavations at Ma-Wang-

[a] Deerr (1), p. 536.
[b] Dermigny (2), p. 441.
[c] Coombes (1), pp. 113–14.
[d] The only evidence we have for the *frangourinier* in Indochina is in the work of the l'Abbé Richard (Richard (1), vol. 1, p. 335) who observed: 'écorce, sous une meule tournée par un bœuf'.

Tui[1] in Chhang-Sha[2], Hunan in 1972, discovered 312 bamboo strips on which names of foods and cooking methods were written. Strip numbers 115 and 121 both contained the character *thang*[3] which Chinese scholars suggested should be read as *thang*[4] or sugar.[a] Considering the state of sugar-making technology in the –2nd century it must have been a syrup or an amorphous sugar. If this syrup was not imported, we have clear evidence that the peoples of the inland had sugarcane at the same time as the coastal Yüeh. It is reasonable to suppose that they possessed the pounding and mashing methods described above for south of the ranges.

The first documentary evidence for extraction machinery appeared during the Thang dynasty. The Chinese scholar Chi Hsien-Lin[5] has recently discovered and published an edited version of a fragmentary document of less than several hundred characters from Tun-Huang, Pelliot number P 3303, which was written on the back of a *sutra* manuscript. Though this document, provisionally dated at the +9th to +10th centuries, contained erroneous characters and lacunae, it is probably the earliest detailed account of sugar-making technology in Chinese. It is also extremely important for the light it throws upon the transmission of sugar technology from India to China via the medium of Buddhist monks during the Thang. The entire edited version of it is translated below, but here let us examine the lines concerning the extraction machinery which read:[b]

When making [sugar] first take the stalks of sugarcane, remove the tops and leaves, cut them into [lengths] of five *tshun* [15 cm] and put them into a large wooden mortar (*ta mu chhiu*[6]). The oxen drags [the pestle] and the juice is pressed out.

Chi interpreted this passage as crushing between millstones (*mo shih ya cha*[7]), but the text does not mention mill-stones.[c] Mazumdar suggested that it referred to an Indian *kolhu*, an annular mortar with an animal-driven pestle[d] (see Figs. 59, 60, 61[e] and 62) and I completely concur with her judgement.

In passing it should be noted that this text mentioned the cultivation of sugarcane under oasis conditions around Tun-Huang in the +9th to +10th cen-

[a] Hu Nan Sheng Po Wu Kuan ... (1). *shang*, pp. 140 and 154; Chang (3), p. 57 and Mazumdar (1), p. 39.
[b] Chi (1), pp. 124–5.
[c] Chi (1), pp. 128 and 131.
[d] Mazumdar (1), p. 95.
[e] Mazumdar was the first to direct attention to the Jain manuscript *Mahāpurāṇa* copied at Palam near Delhi in +1540 (Mazumdar (1)). It has a folio which contains the first illustration of a *kolhu*, and is in fact the earliest representation of a sugarcane mill in the world. Mazumdar ((1), p. 110), who only examined the illustration briefly, has claimed that it represented a vertical two-roller mill and that its early +16th century dating gave India priority for the invention of the vertical two-roller mill. The illustrations provided in Figs. 60 and 61 demonstrate beyond doubt that the equipment in question is a *kolhu*. Mazumdar was not only erroneous as regards the type of mill, but in respect to the location and date of copying as well. Mazumdar gave Mathura and +1532, but Dr Saryu Doshi, the authority on Jain painting and author of *Masterpieces of Jain Painting*, has informed me in a personal communication of Nov. 1987 that it was copied at Palam, near Delhi in +1540.

[1] 馬王堆 [2] 長沙 [3] 唐 [4] 糖 [5] 李漢林
[6] 大木臼 [7] 磨石壓榨

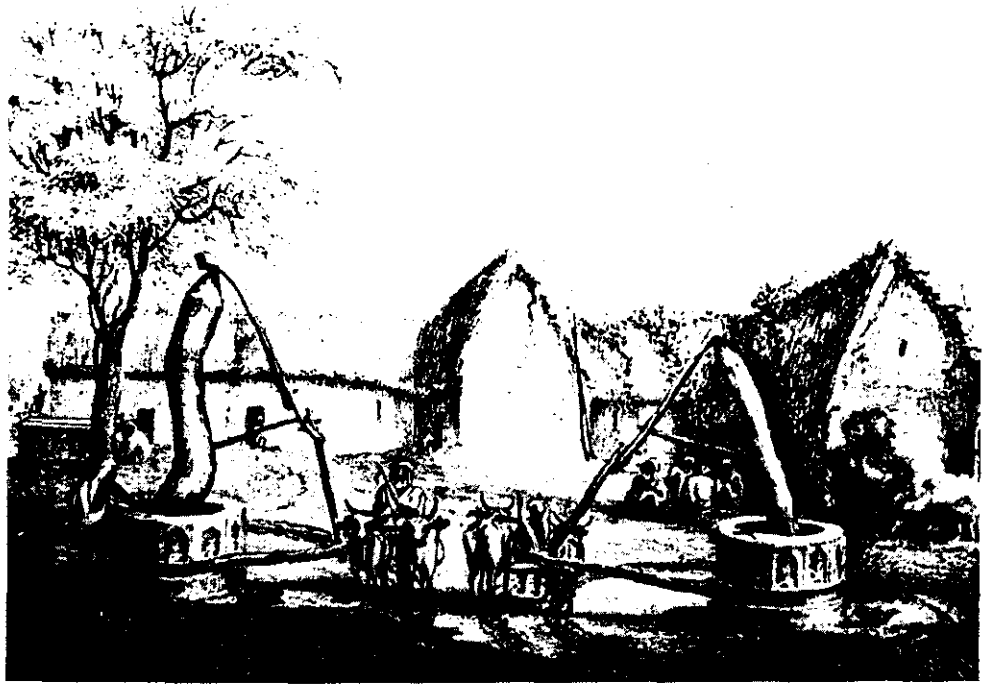


Fig. 59. A village 'factory' with two *kolhus*. The *kolhu* is an annular mortar with a large pestle activated by animals. This scene entitled 'The Sugar Mills at Belaspore' (in India) was drawn by Major Parlby, Kaul (1), opposite p. 292.

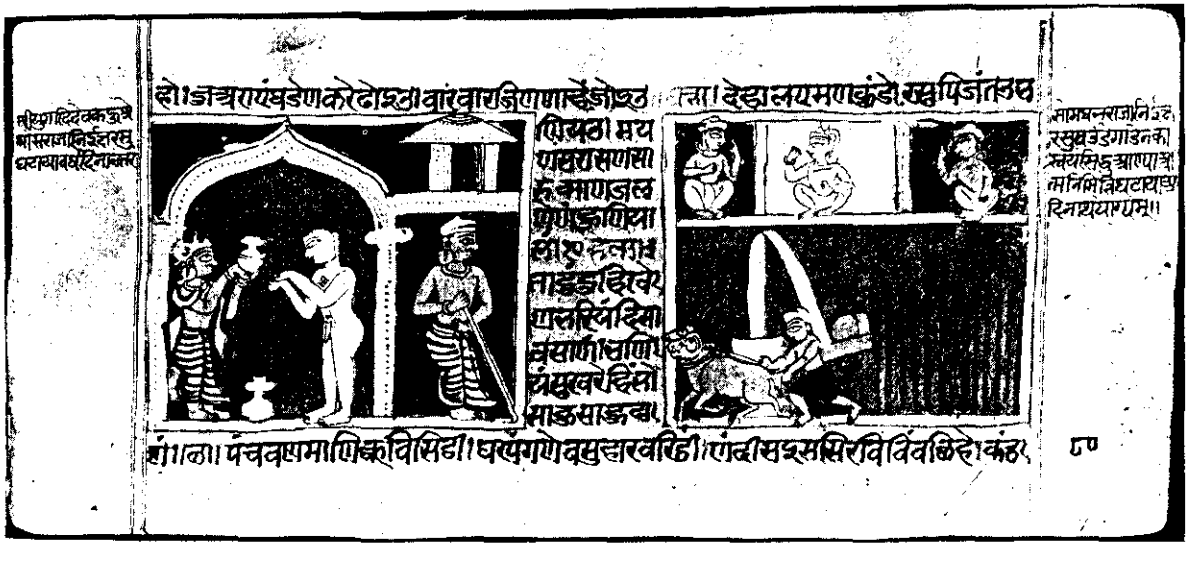


Fig. 60. The folio from a manuscript of a Jain text, the *Mahāpurāna*, copied at Palam near Delhi in +1540. In the left panel we can see Rishabha, the first Jain Thirankara, breaking his fast by drinking sugarcane juice from his cupped hands, see Doshi (1), pp. 90–9. In the lower right panel there is a sugarcane field and a *kolhu* sugarcane mill (annular mortar and pestle) set in motion by two oxen. This is the first illustration of a *kolhu*, and is in fact the earliest representation of a sugarcane mill in the world. Kind courtesy of Dr Saryu Doshi for providing a colour slide of this folio and the Trustees of the Digambara Jain Bada Mandir, Jaipur.

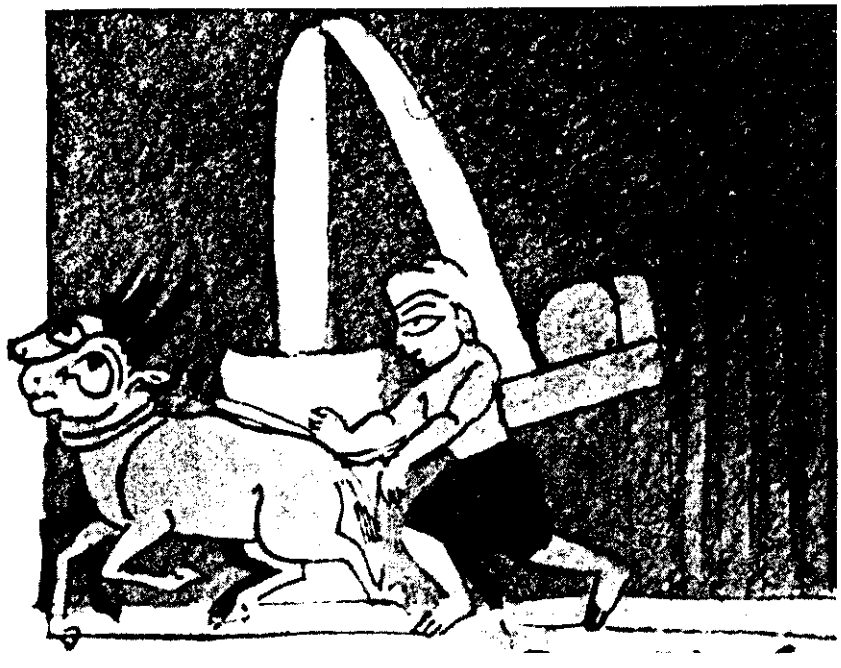


Fig. 61. Detail of lower right panel in Fig. 60. Pieces of sugarcane are dropped into the mortar. The rotating pestle is pulled against the wall of the mortar by the beam with stone weights which aids grinding the juice from sugarcane.

turies.[a] This is a subject of controversy as Tun-Huang lies 42°N of the equator, which puts it well outside the range in which sugarcane is cultivated in China today. However, we have seen previously (p. 186) how temperatures during the Thang were considerably higher than at present, and as sugarcane has been grown at Tiflis in Persia and Gaeta in Italy both 41°N during the +20th century I see no reason to doubt the authenticity of this remark.[b]

It is possible that the *kolhu* first arrived in China from India at the time when new crystallisation techniques were introduced by the so-called technological mission to India in +647. This mission is better discussed under the heading crystallisation, but here suffice it to say, that it would be logical for Indian Buddhist monks to use their own crushing techniques when giving demonstrations in China to reduce the chances of failure. Mazumdar has summarised the evidence for the antiquity of the *kolhu* in India, and suggested that it is the *mahāyantra* of the Buddhist Jatakas and Hindu literature dated at about +100.[c] It is

[a] See translation of relevant passage in this text given in *The Tun-Huang MS P 3303 on sugar making*, pp. 373–5.

[b] Deerr (1), p. 72.

[c] Mazumdar (1), pp. 90–6. There is additional evidence not noted by Mazumdar that can be marshalled to support this suggestion, namely that the name of the machine in ancient Jain literature is *Kolluka*, of which *kolhu* appears to be a corruption, see Jain (1), p. 91; Gopal (1), p. 61; Hinüber (1), pp. 101–2.

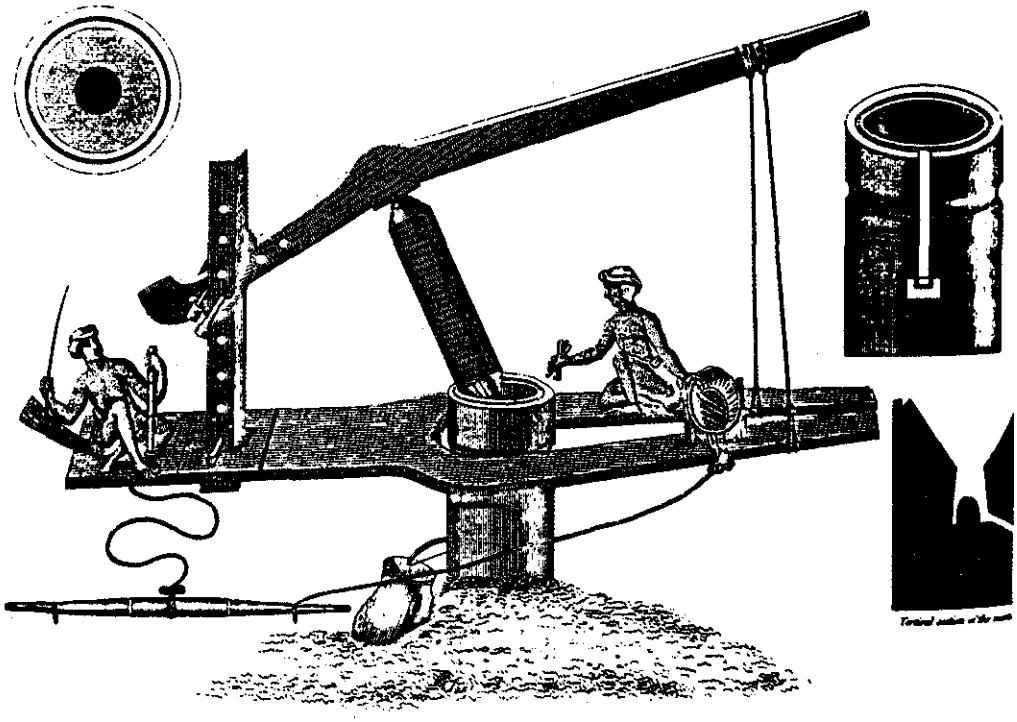


Fig. 62. A sophisticated animal driven *kolhu* (mortar and pestle) in Chinapatam, early 19th-century India; East India Company (1), p. 24. Similar machines of this type of technology crushed sugarcane in north and south India. Deerr ((1), p. 534) envisaged that Hesiod (−8th century) described a simpler version of this machine in his *Works and Days*.

possible that it may have had an even more ancient origin in Greece because Deerr accepted the machine described in Hesiod (−8th century) as a *kolhu*:[a]

Hew a mortar three feet in diameter and a pestle three cubits and an axletree seven feet long, for look you, it is very serviceable thus; but if you would cleave it eight feet you might also cut from it a mallet.

Deerr commented:[b]

This passage has given difficulty to some commentators, especially in the meaning to be given to *axona*, *ἄξονα* translated axletree. This is evidently the member upon which the driver sits, and which is attached to and rotates around the fixed mortar.

A crushing apparatus with this type of generic technology was illustrated in Fig. 62. It would appear therefore that the *kolhu* was very ancient milling equipment with a continuous history in India from about the time of Christ to the 20th century. The application of the *kolhu* for expressing seed oil and sugarcane juice in 19th-century India was described in detail by Grierson,[c] but in areas

[a] Translation from Banks via Deerr (1), p. 534.
[b] Deerr (1), p. 534.
[c] Grierson (1), pp. 50–6.

apart from India its use remains obscure.[a] The evidence from the Pelliot manuscript indicated its presence in China during the Thang, and an introduction by Buddhists appears likely. We shall presently see that there was wholesale introduction of Indian technology into China for the clarification and crystallisation of sugarcane juices. For West Asia, there are garbled reports of mortars in Palestine at the time of the crusades, so we cannot rule out the presence of the *kolhu* at that time.[b] In all areas, commencing from the +10th century, we see the rise of the edge-runner mill which was superior technology.[c] By the +12th century, the edge-runner became the dominant technology for crushing sugarcane and expressing oil, from China through the Near and Middle East and Morocco to Spain.[d] The only exception was India where it was probably not employed, and the *kolhu* remained important until the late 19th century.

The edge-runner comprised a large single disc rolled on its edge on a platform or within a race, see Figs. 63, 64 and 65. The disc was usually in the range of 4 to 6 feet and could weigh hundreds of kilos. In addition to crushing sugarcane and oil seeds, it has been employed for road construction (Fig. 66). Medieval applications in Europe included poppy, mustard, tanning, pigment and mortar mills.[e] After the +17th century manufacturers utilised it for processing snuff, pipe clay, china, cement, gun-powder and crushing apples for cider (Fig. 67).[f]

The origin of the edge-runner remains obscure. Although Drachmann has described what has been interpreted as a small edge-runner for crushing olives, on a sarcophagus in the Palazzo Rondanini, Rome, it is after +1000 before installations in Europe performed the operations listed above.[g] In Europe the edge-runner was first mentioned for crushing cane in an +1175 edict of the Monreale Cathedral in Sicily by its Arabic name *massara*.[h] It is most likely that the edge-runner, in the form used in medieval times, came to Europe from the east. The edge-runner was known in Arabic as *massara* (press) and *hajar* (stone), being descriptive names for the same machine.[i] Ibn Hauqal first recorded *massara* in +978, and *hajar* first appeared in an Arabian papyrus dated +750 to +800.[j] The edge-runner thus emerged in the Near East during the +8th cen-

[a] Coombes ((1), pp. 113–14) related that it was called the *frangorine*, and was used in Mauritius during the +17th century.

[b] Albertis Aquensis in +1108 through Ritter (1), p. 391, Albert von Aachen in c. +1125 through von Lippmann (4), p. 289, and Barthelomaeus Anglicus in +1230 through von Lippmann (4), p. 302.

[c] The lack of safety constituted the most serious deficiency of the *kolhu*. The crushed sugarcane had to be removed from the mortar while the pestle was rotating. Watt ((1), vol. 6, pt 2, p. 183) remarked that this operation was most difficult for anyone but a left-handed person to perform.

[d] Daniels and Daniels (4).

[e] Reynolds (1), p. 70.

[f] Reynolds (1), p. 74. Diderot has a very striking illustration of processing apples for cider with a combination of edge-runner followed by a beam press, see Gillispie (2), pl. 23.

[g] Drachmann (7), p. 42 and Reynolds (1), p. 72.

[h] Ritter (1), p. 402

[i] See Trasselli (1), p. 50 for a discussion of *massara* and Berthier (1), p. 237 for *hajar*.

[j] For Ibn Hauqal see Wiedemann (23), vol. 2, p. 180 and the papyrus documented in Sauvaget (1). Sauvaget ((1), pp. 34–6) also suggested that the *hajar* in this manuscript is a roller mill, but this was convincingly refuted by Berthier (see Berthier (1), p. 237).



Fig. 63. An edge-runner and wedge press in early +16-century Hispaniola. A vertical wedge press for a secondary extraction of the bagasse is partially concealed behind the edge-runner. At the upper far right an overshot waterwheel is probably activating a horizontal two-roller mill. This plate from Theodore de Bry (2) of +1595 (pl. *Nigritae Exhaustis Venis Metallicis*, no. 2), which was first published in the *La Historia de Mondo Nuovo* of +1565 by Jeronimo Benzoni, has been described as fanciful technology, see Mintz (1) [description of plate between pp. 78–9]. Although the negro figures look like idealised Caucasians, there is no reason to believe that de Bry inaccurately represented the technology. In de Bry (2) there is a long footnote (fn. 5 to pp. 143–5) explaining the process of sugarcane manufacture which I have not seen cited elsewhere (courtesy of the Mitchell Library, State Library of NSW, Sydney).

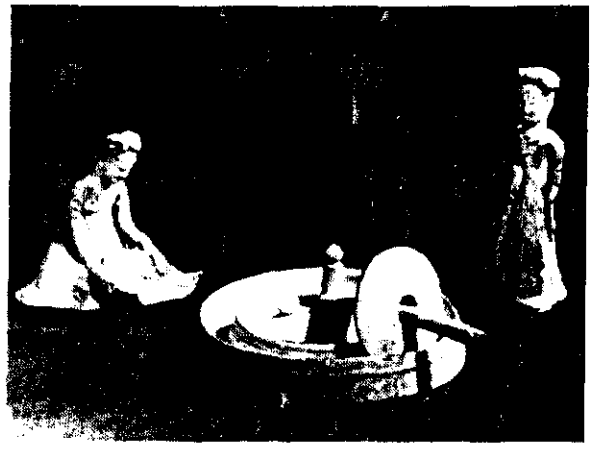


Fig. 64. A model of an edge-runner travelling in a race with figurines from a Ming Chi tomb dating from the Sui dynasty (+581 to +618); from Garnsey & Alley (1), p. 11.

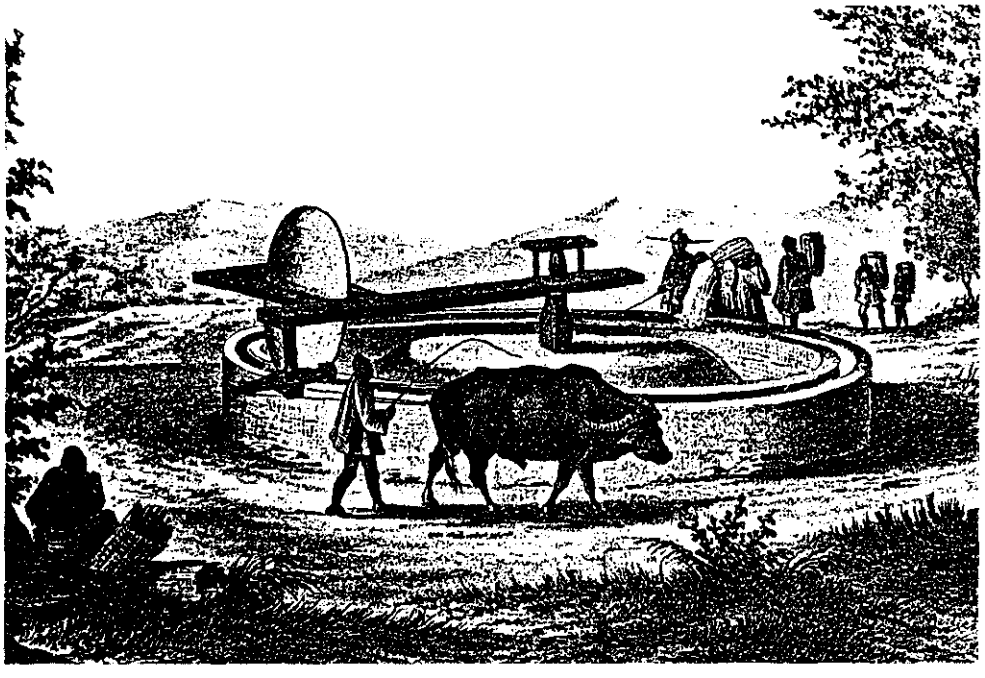


Fig. 65. A large edge-runner in 19th-century Kuang-Tung for crushing beans and bones, West (1), pl. 4.



Fig. 66. An edge-runner for compacting roads in modern Afghanistan. It is drawn by a horse and steadied by the man running alongside it; Duché (1), frontispiece.

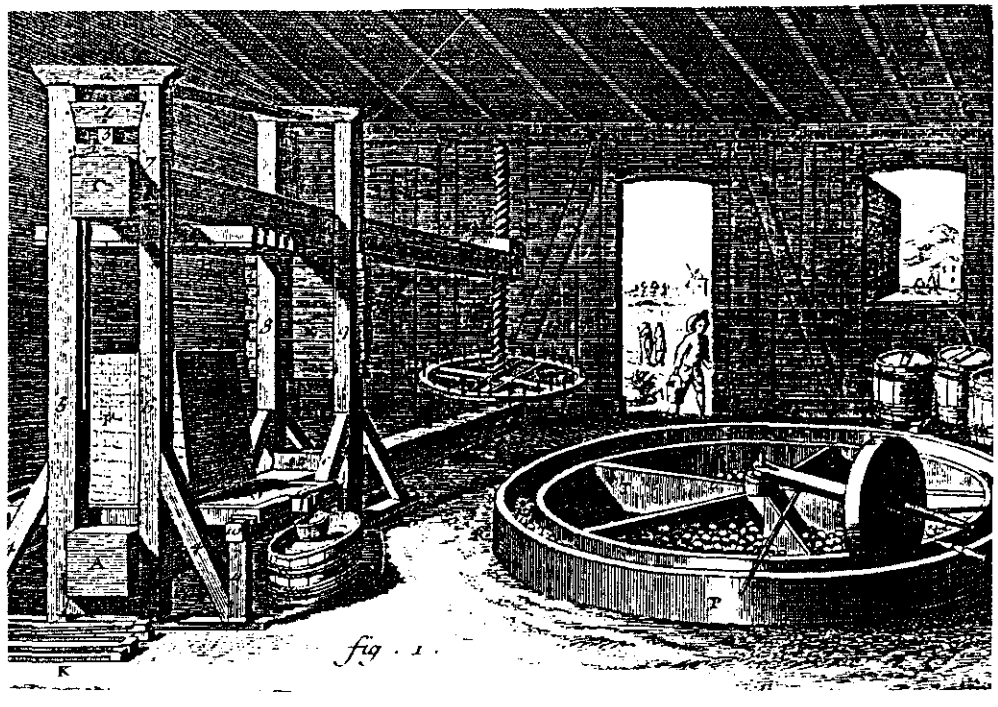


Fig. 67. An edge-runner with a secondary beam press for extracting juice from apples for cider in +18th-century France from the *Encyclopédie* of Diderot; through Gillispie (2), pl. 23. The combination of an edge-runner with a static press was used for processing sugarcane over a wide area ranging from China to Spain from the +12th century.

tury as a machine for crushing sugarcane and pressing olives. The literary evidence is backed up by extensive archaeological data from Persia and Palestine.[a] Chinese sources recorded the edge-runner earlier, around +400 for processing oil seed, and in Volume 4, part 2, China was considered as a possible place of origin.[b] This time scale and known diffusion routes make this theory highly attractive. The edge-runner served as one of the major instruments for crushing oil seeds during the Thang, but the first direct evidence we have for sugar processing dates from the *Thang Shuang Phu* of c. +1154, and is obviously related to oil processing. This was the first text to describe the edge-runner and the milling process:[c]

The cane edge-runner mill (*chê nien*[1]) used oxen to press the chopped cane. [The single] roller is made of a large hard stone six or seven *chhih*[2] [c. 2.15 m] in height and a thou-

[a] See review in Daniels and Daniels (4).

[b] Vol. 4, pt 2, p. 403. There is some discussion about whether the character *nien*[3] refers to an edge-runner or a trip hammer, see Twitchett (3), p. 533. Yet, there is no doubt that the edge-runner was present in China from the +6th century at least; see the charming model unearthed from the Ming Chi tomb figures, dating from the Sui dynasty (+581 to +618) illustrated in Fig. 64.

[c] *TSP*, pp. 4a–4b; Liu & Liu (1), p. 15.

[1] 碾磨 [2] 尺 [3] 磨

sand odd catties [c. 600 kilos] in weight. Beneath hard stone is used to make the trough base, with a circumference of more than one *chang*[1] [c. 3 m] ...

Next [the cane pieces] are put beneath the edge-runner. If there is no edge-runner, they are pounded in a mortar. [The frass that remains after] grinding is finished is called refuse (*po*[2]). Next steam the refuse. Once completely steamed, remove it from the earthen steamer (*tsêng*[3]) and put it in the press. After extracting all the juice possible, pour it into a cauldron (*fu*[4]) to boil, but continue to steam the crude refuse [in a steamer] above [the cauldron]. When the juice has [concentrated to a syrup and] comes within seventy percent of being finished pour it into an earthenware jar (*wêng*[5]). At this point the steamed refuse is also ready for pressing. Continue to boil and steam successively in this way.

Here we find for the first time the combination of edge-running[a] with static pressing, a method that was subsequently described in the Middle East, Spain and the New World.[b] The two-stage process continued into the +18th century and Diderot illustrated it for processing apples for cider in his great *Encyclopédie* (see Fig. 67).[c]

I suggest that the edge-runner had its origins in seed oil production in China. A good description of the generic technology appeared in the account of oil extraction in Manchuria by Alexander Hosie during the late 19th century. He first remarked on the most primitive mill:[d]

A large stone wheel of dressed granite about ten feet in diameter and two and a half feet thick at the axis, gradually contracting to a foot at the rim, which is smooth, revolves in a circular well from thirty to thirty-six inches broad, paved by stone and bounded on each side by a low wall of concrete two to three feet high.

Hosie then recorded a more 'modern' edge-runner and the methods of feeding it with seed:[e]

Round comes the cylinder and crushes the beans into wafers, which at the next revolution are swept from the platform into the gutter by the share in front of the feeder. The first process, that is, the crushing of the beans is now complete. The bean wafers are then removed from the gutter in baskets and steamed. A number of brick furnaces two to two and a half feet high are fitted on the top, with large open shallow circular iron pots more than half full of boiling water. A couple of inches below the lip of each pot a

[a] Mazumdar ((1), pp. 97ff) argued that the mill was a *kolhu*, principally because she does not believe that large edge-runners of this type were feasible. She was not aware of 20th-century reports of large edge-runners in China and Iran, see Hosie (6), p. 218 and Wulff (1), pp. 296–300. The translation of Shiba by Elvin (Shiba (1), p. 91) described the machinery in the *TSP* in this way: 'oxen were used to work the crushing rollers'; this is also erroneous.

[b] See al Nuwairī (+1279 to +1332), *Nihāyat al-arab fī funūn al-adab* (Aim of the Intelligent in the Arts of Letters) tr. in Deerr (1), p. 91. Dating for Al Nuwairī from Sarton (1), vol. 3, pt 1, p. 620. Also see de Caumont in Grange (1), p. 117 for Spain; de Bry (2), plate *Nigritae Exhaustis Venis Metallicis* no. 2 for Hispaniola.

[c] Gillispie (2), pl. 23.

[d] Hosie (6), p. 218. There is a similar report in Wulff (1), pp. 296–300 of the edge-runner in 20th-century Persia.

[e] Hosie (6), pp. 220–1 and pl. opp. p. 220.

[1] 丈 [2] 粕 [3] 甑 [4] 釜 [5] 甕

circular wooden grating is inserted, and over this is spread a square piece of course hempen cloth. When the water boils the steam ascends through the grating and cloth, and on the latter a basketful of bean wafers is spread and steamed for a quarter of an hour, when they are sufficiently soft to be moulded into cakes for the oil-press. I have weighed these bean wafers before and after steaming and found the weights to be 54.5 and 60.5 catties respectively.

This is a fuller version of the telegraphic report about crushing sugarcane given in the *Thang Shuang Phu* written more than 700 years earlier. Studies of 20th-century cottage industry oil production in Iran revealed that the methods practised there were essentially the same as those documented for China in the +12th and +19th centuries, except that the Iranians did not steam the cake before the second pressing.[a] The Chinese process would be more efficient for sugarcane because of dilution steaming. With soya beans Hosie noted a 10 per cent increase due to absorption of water.[b] I suggest that the Chinese method of crushing sugarcane with edge-runner mills and steaming was primary, and derived from oil milling. As it moved westwards towards Persia the steaming component was discarded due to fuel shortages, and we have not found a single record of this latter process outside China. Steaming was a preferred ancient Chinese technique and would have been readily applied to juice extraction.[c]

The actual second press employed for extracting cane juice was not extensively described, but I agree with Mazumdar that it was most probably a traditional Chinese rope-clutch press.[d] It first appeared in the *Thang Shuang Phu*:[e]

A press container (*cha tou*[1]), also called a bamboo bag (*chu tai*[2]) four *chhih*[3] [c. 1.2 m] high and plaited from spiny bamboo grown that year, is used to press cane [refuse]. A jujube pestle (*tsao chhu*[4]) is used for pounding the cane into the press container. A press tray (*cha phan*[5]), similar to the wine press trough bases of the present day, [are used] for stabilizing the container. The press base (*cha chuang*[6]) secures the tray. On the press base a large beam is mounted and a windlass (*chuan chou*[7]) [is fixed] below, that pulls the rope to pressure [the large beam].

Joseph-Antoine Valcarcel described the rope-clutch press in +18th century-Spain for the secondary pressing of sugarcane. There is reason to believe that it was employed in the Spanish and Portuguese New World colonies.[f] However secondary pressing equipment was not uniform as we find a completely different

[a] Wulff (1), pp. 296–300.

[b] Hosie (6). Efficiency in this context is a difficult term. While more sucrose may have been extracted with steaming, there would be higher labour costs and more energy used. The more 'efficient' steaming method may have resulted in higher costs for fuel.

[c] For example the Chinese have always steamed rather than baked bread, see Vol. 5, pt 4, p. 27.

[d] Mazumdar (1), p. 100.

[e] *TSP*, p. 4a; Liu & Liu (*1*), p. 15.

[f] For Spain see Coulter (1), p. 257. Secondary presses were known as *gangorras* in early Brazil, see Mauro (1), p. 204.

[1] 榨斗 [2] 竹袋 [3] 尺 [4] 棗杵 [5] 榨盤
[6] 榨牀 [7] 轉軸

beam press in Egypt.[a] Spain and the Spanish colonies retained secondary pressing when they shifted from edge-running to roller milling for the primary crushing operation. Roller milling was the next major change in technology on the world scale, but before we examine its development, we must look at the significant advantages of the alternative techniques developed earlier in China.

(ii) *Alternative techniques in China*

Before returning to the mainstream of methods in China let us note a curious method of extraction illustrated for the Amami Islands during the +18th century (see Fig. 68). Stalks of sugarcane made flat and pliable by beating with sticks were stretched between two posts, each end then joined to bar handles which were twisted in opposite directions, and the juice literally wrung out of the cane.[b] This has no significance for the mainstream development of extraction, but it may be the survival of some primitive method deriving from the Chinese area of influence, and be relevant for prehistorical reconstructions in the future.

I have suggested above that north and south of the ranges, juice was first expressed by pounding cane in a mortar. As the need for greater production arose at the household level, sugarcane was broken up on a base with a single travelling roller in the south, and tilt-hammers in the north and south.[c] These methods lasted into the +17th and +18th centuries. I surmise that greater quantities of oil and sugar required by the Buddhist monasteries during the Thang probably promoted the adoption of the edge-runner which was capable of processing larger volumes of sugarcane. This technology was employed concurrently with the simpler pounding techniques at the household level.

In Fukien the first literary reference to crushing sugarcane appeared in the +1182 gazetteer, the *San Shan Chih*[1]:[d]

> Pound bamboo cane (*Saccharum sinense*) in a mortar and steam [the refuse to extract the juice. Sugar production] thrives in Sugarcane Sandbar Department (*Kan Chê Chou Shu*[2]) in Hou-Kuan[3].

This is a laconic description of a mortar combined with steaming and pressing, possibly using the rope press explained above. The following source makes it plain that the Chinese indeed possessed an alternative contemporary technology to the edge-runner followed by static pressing. It occurred in the *Nung Sang*

[a] See extract from al Nuwairī (+1279–1332) in Deerr (1), p. 91.

[b] See *Nihon Sankai Meibutsu Zue, Kan* 3, pp. 17b–18a. This method operated on the same principle as the early Egyptian grape presses dating from −2000, in which a bag containing grapes was twisted in opposite directions, see reconstructions in Hodges (1), p. 101.

[c] The pedal tilt-hammer appeared in China from c. the −1st century, see Vol. 4, pt 2, p. 184.

[d] *San Shan Chih*, p. 8083.

[1] 三山志 [2] 甘蔗洲署 [3] 候官

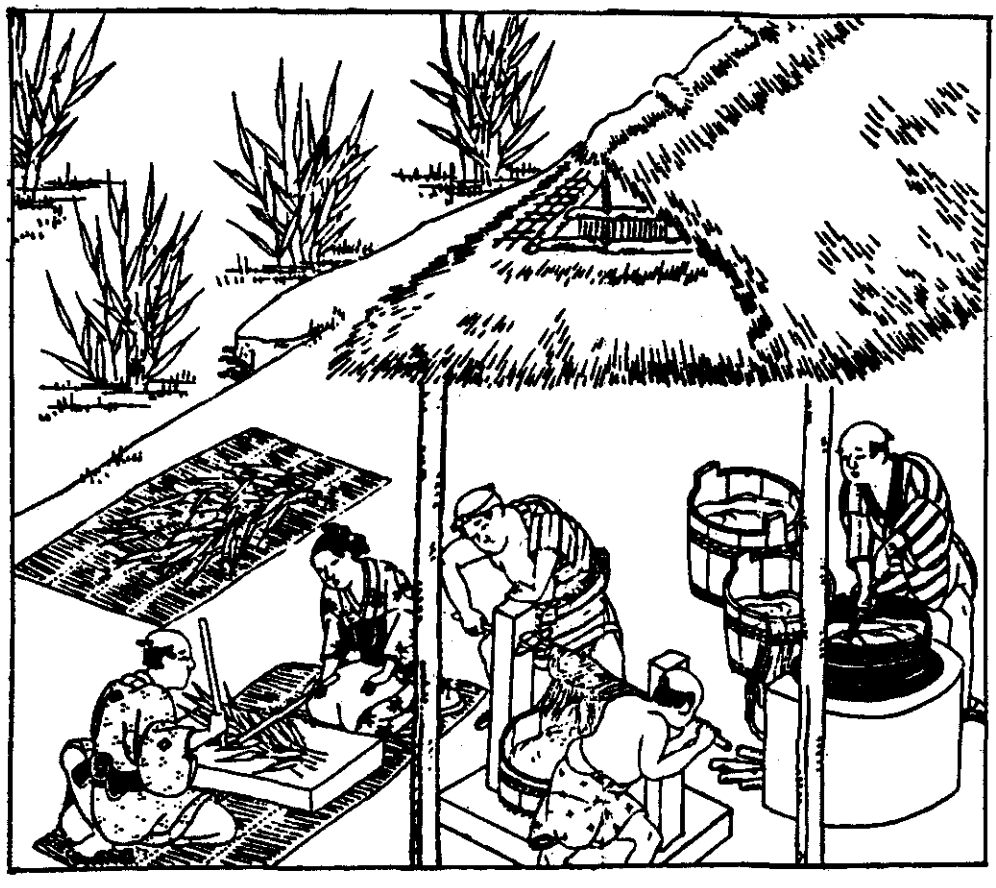


Fig. 68. An unusual method of extraction in the Amami Islands lying south of Japan; from the *Nihon Sankai Meibutsu Zue, kan* 3, pp. 17b–18a, of +1754. This illustration depicts the entire sugar-making process as practised there. On the left sugarcane stalks are beaten to make them flat and pliable, in the middle the beaten stalks are twisted to wring the juice from them, and on the right a man is boiling the extracted juice.

Chi Yao of +1273 which was compiled under Imperial sponsorship during the late +12th century to promote agriculture in north China. The method outlined was evidently selected and publicised, probably so that agriculturalists without access to large edge-runner installations, could participate in the sugar making with equipment already available for cereal processing. The text reads:[a]

Strip the tops and leaves from the stalks that have just been harvested and cut them [into pieces] two *tshun* [6 cm] long. Pound and pulverise [the cut cane pieces] in a treadle-operated tilt-hammer. Fill a closely plaited basket or a cloth bag [with the cane refuse] and extract [more] juice by pressing.

There is no further information on the second pressing operation, but Chinese sources only recorded two static presses – the rope press described above and the wedge presss, which has been examined in detail in an earlier Volume (see

[a] *NSCY*, ch. 6, p. 14a.

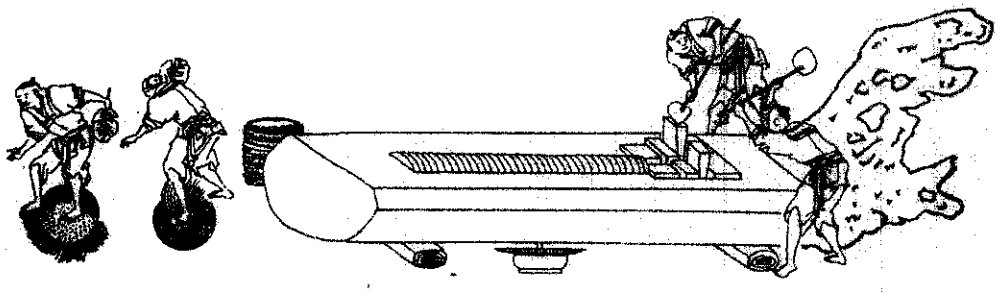


Fig. 69. Pressing peanuts in a wedge press to obtain oil at Swatow during the 1890s. Prior to the +17th century a similar wedge press may have been used for extracting juice from sugarcane. On the left two men are preparing the peanuts for pressing. The residual cakes were used as fertilisers on sugarcane fields; China Imperial Maritime Customs (1), vol. 2, pp. 158–9.

Fig. 69).[a] The *Nung Sang Chi Yao* method cited here persisted for at least another 350 years because we find exactly the same information repeated in the *Nung Chêng Chhüan Shu* of +1639.[b]

By the beginning of the +16th century the tilt-hammer method had been combined with a diffusion process. The +1503 gazetteer for Hsing Hua prefecture[1] in Fukien related:[c]

Black sugar (*hei-thang*[2]) is made by boiling sugarcane [juice]. In the eleventh lunar month after the sugarcane ripens, it is cut and placed in a treadle-operated tilt-hammer (*tui*[3]) and pounded until it becomes a pulp. [The cane frass] is stored in a large bucket with a hole in the side near the bottom. As each layer of sugarcane [frass] is put [in the bucket] sprinkle it thinly with ashes building them all up solidly. When [the bucket] is full (*chi phu*[4])[d] pour hot water from the top [and allow it] to soak through to the bottom. Another large bucket is used to receive the liquid that flows out from [the hole] in the bottom [of the bucket containing the cane frass]. After a while [the extracted juice] is taken and put into a pan (*fu*[5]) and boiled (*pheng-lien*[6]).[e]

Nearly thirty years later in +1530, a gazetteer described exactly the same technique in Hui-An county[7] of Chhüan-Chou prefecture[8], another leading sugar-producing area in Fukien during the Ming dynasty.[f] As stated earlier, washing and diffusion techniques are inherently more efficient than simple mechanical

[a] Vol. 4, pt 2, pp. 206 and 209

[b] *Nung Chêng Chhüan Shu*, ch. 30, p. 17a.

[c] +1503 *Hsing Hua FC*, ch. 12, pp. 11a–11b.

[d] Tai (1), p. 104 note 13 suggested that *phu*[9] (referring to various kinds of rush) is a substitute character for *pho*[10] (frass) due to their phonetic similarity. However, these are not exact phonetical equivalents and taking *phu* in the sense of frass does not fit in with the context. In the absence of other definite evidence it seems more logical to follow the text of the +1530 *Hui-An HC* 5/20a–20b, which is a simplified version of the text in the +1503 gazetteer and reads, '*chi thung man*[11] when the bucket is full'.

[e] The text is not explicit as regards boiling but perhaps the frass and the juice was boiled.

[f] +1530 *Hui-An HC*, ch. 5, pp. 20a–20b.

[1] 興化府 [2] 黑糖 [3] 碓 [4] 及滿 [5] 釜
[6] 烹煉 [7] 惠安縣 [8] 泉州府 [9] 蒲 [10] 粕
[11] 及桶滿

extraction. These more efficient methods would remain paramount as long as there was sufficient fuel to boil off the water added to the juice during diffusion. Daniels & Daniels have speculated that the diffusion techniques used in the Middle East were curtailed with deforestation, and that this triggered the use of static presses and edge-runners.[a] They cited Lombard (1) which suggested that the general deforestation of the Mediterranean arose due to the rise of metal smelting and the sugar industry. Smelting has also been cited as a cause of deforestation in China along with the building of large Imperial palaces and large ships for the Chinese navy.[b] In central China it was mainly attributed to the opening up of the mountainous areas and the highlands by Han Chinese agriculturalists. The expansion of agriculture in these areas gained momentum after the +16th century with the introduction of New World crops such as maize and the sweet potato. Sugarcane cultivation also expanded after the +16th century with the spread of the money economy, and the large amounts of fuel required for sugar boiling aided the opening up of agricultural land south of the ranges, but ultimately led to deforestation as cultivators did not replace the trees that they felled. In Daniels (4) I have shown the acute deforestation in Fukien between the +16th and +18th centuries, and suggested the lack of fuel as the immediate reason for sugar millers adopting the two-roller vertical sugar mill because this machine left the frass of crushed cane in a state suitable for fuelling the furnaces.

(iii) *Crushing sugarcane with grain mills in China and Europe*

Can sugarcane be crushed with a grain mill? Such claims have been made for the West, and evidently for China as well because the 1872 gazetteer for Nan-Phing county[1] in the interior of Fukien wrote:[c]

> Insert sugarcane into a *mo*[2] [literally a rotating grain mill], and the juice is expressed by oxen turning [the *mo*]. [The refuse] is steamed [and the juice boiled to make sugar].

When processing cereals the *mo* was fed with grain through a hole in the upper rotating stone, falling through the stone and being ground between the stone and the base. But I think that it would not be possible to gravity feed chopped up sugarcane into a *mo* for grinding. Von Lippman and Deerr have recorded the grain mill, the *mola versitalis*, as crushing sugarcane during the middle ages and the Renaissance in the West.[d] Their evidence rested on a painting of sugar manufacture in Sicily in the *Nova Reperta* of Stradanus (c. +1585?). This was probably the most widely reproduced painting of sugar manufacture in the

[a] Daniels & Daniels (4).
[b] See part 42b on Forestry, in this Volume.
[c] 1872 *Nan-Phing HC.* ch. 28, p. 3b.
[d] Von Lippman (4), p. 413 and Deerr (1), p. 535.

[1] 南平縣 [2] 磨



Fig. 70. This painting has been widely reproduced by historians of technology as representing sugar manufacture in +16th-century Sicily. It was intended to depict all aspects of sugarcane processing including harvesting in the field, transport by donkey, crushing in a two-stage process (grain mill in left foreground, and screw press in left background), through boiling to the end product, sugar loaves. It is a pastiche compiled from various sources and is inaccurate. The grain mill, the *molas versatalis*, powered by a vertical watermill, could never have crushed sugarcane in the manner shown. From the *Nova Reperta* pl. XIII of Stradanus (c. +1585) through Baxa & Bruhns (1), p. 30.

world (see Fig. 70), but need not be seriously considered because it was what Dutch engravers termed a *compilatiewerk*, or scene artificially brought together from various sources.[a] The artist knew nothing of sugarcane morphology as two leaves arise from each node, and on the left the artist depicted a vertical water mill with an associated grain mill, which has been plagiarised from the +1567 edition of Vitruvius.[b] Von Lippmann and Deerr have accepted this mill as an authentic *mola versatalis* in a plausible context. Daniels & Daniels commented on the *mola versatalis*: 'Our personal experience with modern cutter grinders, indicates that continuous pressure from a piece of wood, would be absolutely necessary for feeding and it is a most difficult or impossible task.'[c] Agricola described and illustrated the grinding of ore in a mill of this type, but

[a] Daniels & Daniels (4), pp. 500–1. For examples of reproductions of this painting see von Lippman (4), frontispiece; Deerr (1), pl. 6; Singer, Holmyard, Hall & Williams (1), vol. 2, figs. 340 and p. 370.

[b] See Deerr (1), p. 535.

[c] Daniels & Daniels (4), p. 501.

it had a mechanism to raise and lower the millstone for feeding.[a] This was not represented in the *Nova Reperta* illustration, and without further evidence there is no reason to believe that a *mola versatalis* ever crushed sugarcane. This argument is even more pertinent in regard to the *mo* as the large, deep, stone mill would be more difficult to raise. I do not believe that the *mo*, as such, ever processed sugarcane.

In fact in the case of sugar processing in China all evidence shows that the word *mo* did not refer to rotating grain mills, but to a stone roller sugarcane mill. The following statement in the 1841 gazetteer for Hsin-Hui county[1] near Kuang-Chou indicated as much;[b]

> Sugar [is made by] inserting sugarcane between two stones positioned side by side like two *mos* (*i erh shih hsiang-pi ju liang mo*[2]), and oxen crush it by [turning the stone rollers]. One person [sits] on each side [of the rollers], and as the sugarcane is inserted from this side, the bagasse (*cha-tzu*[3]) comes out of the other side. The juice flows down into an earthenware jar (*lou*[4]) positioned in a stone-lined pit dug into the ground (*ti khai shih-chiao*[5]).

It was the similarity between the appearance of a double-stone-roller sugar mill, and two *mos* linked together by gearing that seems to have imparted the meaning of roller to the term *mo*, and it is significant that the Taiwanese called double-roller vertical stone mills *shih-mo*, or stone *mos* in the 19th century.[c]

(iv) The advent of roller milling

I have already elaborated on a number of methods employed around the world for crushing sugarcane, including the mortar and pestle, edge-runner, *kolhu*, *frangourinier*, diffusion with water, and others. At the commencement of the +17th century, the vertical roller mill appeared in the Philippines, China and the New World, after which it gradually gained ascendency until by the 20th century all countries used roller milling, both vertical and horizontal, sometimes combined with some diffusion to the exclusion of other machines.[d] Let us now examine this new milling method and its dispersal on the basis of Daniels & Daniels (4), which indicates that the sugarcane roller mill has its origins with the cotton gin. I have modified the hypotheses in that article in the

[a] Agricola (1), p. 294.

[b] 1841 *Hsin-Hui HC*, ch. 2, p. 71b. Interestingly enough one author even likened the stone roller mill to an edge-runner. Huang Shu-Ching in his *THSCL* of +1736 (p. 57) wrote: 'The sugarcane roller mill (*chê-chhê*[6]) of the present day has two stones that stand erect, resembles two edge-runners (*chuang ju liang nien*[7]) and crushes cane juice. I suppose it is a legacy of the cane edge-runner (*chê-niên i-chih*[8]).' Here the author was probably more concerned with tracing the roller mill back to the *TSP*, and in his eagerness mistook an edge-runner for a *mo*.

[c] Tai (1), p. 111.

[d] Diffusion only remained as a minor technology in certain areas, such as in India.

[1] 新會縣 [2] 以二石相比如兩磨 [3] 渣滓 [4] 漏
[5] 地開石窖 [6] 蔗車 [7] 狀如雙碾 [8] 蔗碾遺製

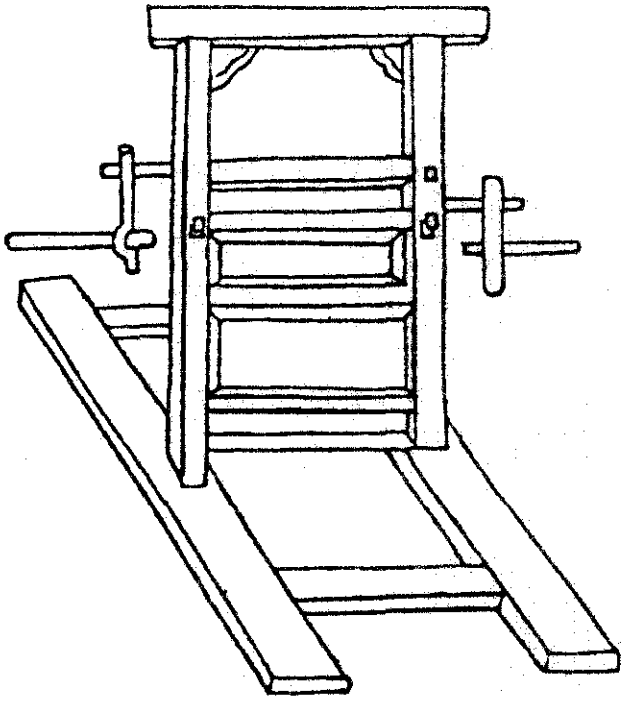


Fig. 71. A cotton gin from the *Nung Shu* of +1313 with rollers independently powered by hand; Vol. 4, pt 2, Fig. 419.

light of additional information, and set out the new schema in the following six points:

1 the sugarcane roller mill evolved from the primitive manually powered cotton gin. The latter had two horizontal rollers (see Figs. 71 and 72), and first appeared c. +1100.
2 the earliest sugarcane mills were merely scaled-up versions of the cotton gin (see Fig. 73). They were manually powered, horizontal, and probably developed in India about +1400.
3 the first two-roller horizontal mill using power was hydraulically operated, and built in the New World from an Indian concept, or more probably independently from the metal rolling or cotton gin analogy somewhere between +1520 and +1530 (see Figs. 74 and 75).
4 animal-powered horizontal mills have a clumsy complex drive, and were probably invented in mid +16th century India (see Figs. 76 and 77).
5 the two-roller mill had to be converted from horizontal to vertical axis layout (see Figs. 78*a*, 78*b*, 78*c* and 79) to obtain a simple animal driven machine. This most probably evolved in China during the late +16th century.
6 engineers in the New World devised the three-roller vertical mill around +1600 from a two-roller concept transferred from China (see Fig. 80). An



Fig. 72. A cotton gin from the 1959 Chung Hua reprint of the original +1637 edition of the *Thien Kung Khai Wu*, ch. 2, p. 42b. The rollers are ungeared, and the operator turns one with his hand, and the other by means of a treadle-stick, which is attached to the roller handle by string.



Fig. 73. A manually powered, horizontal, ungeared two-roller sugarcane mill in +18th-century India. On the basis of its similarity with ungeared roller arrangements, I hypothesise that this type of mill was the prototype for succeeding innovations; Deerr (1), pl. 5, lower.

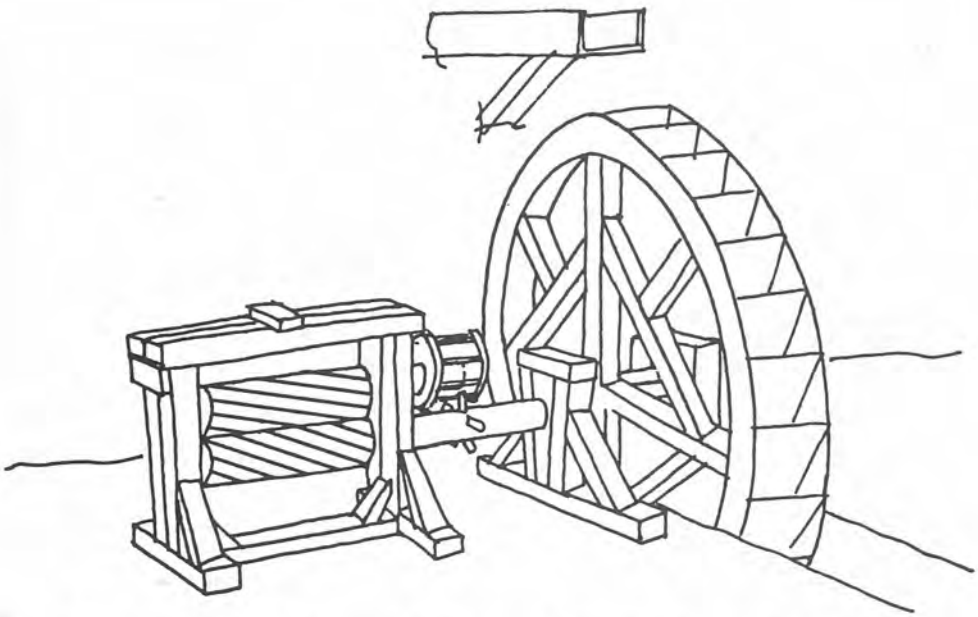


Fig. 74. Reconstruction of a +16th-century Brazilian, two-roller horizontal sugar mill powered by an overshot vertical waterwheel; Sugar Museum, Recife, Brazil, through Barros de Castro (1), p. 684, fig. 3.

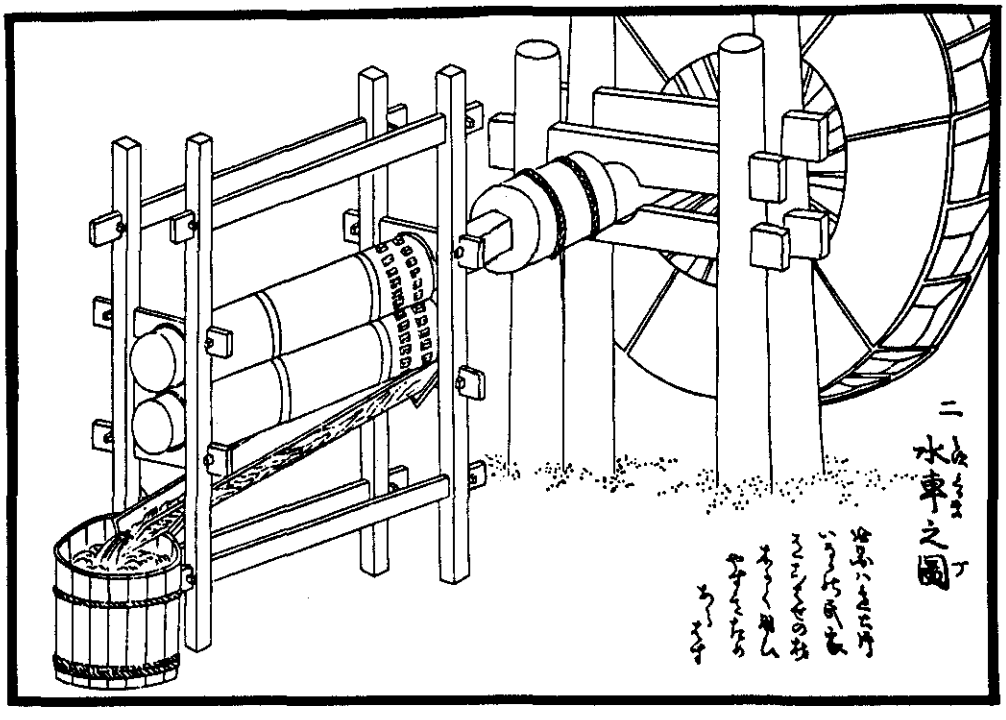


Fig. 75. A two-roller horizontal sugarcane mill driven by a vertical water wheel in +18th-century Japan; *Satō Seisaku Kī*, pp. 9b–10a. Note that the rollers sit one on top of the other without separate bearings. Schwartz ((1), p. 127) implied that the rollers in early horizontal sugarcane mills in Brazil sat on top of each other, and did not have separate bearings (courtesy of the University of Tokyo Library).

engineer in the Ryūkyū Islands independently created a three-roller vertical mill in +1671. Vertical roller mills were standard equipment worldwide until the 19th century.

(v) *The origin of the two-roller, horizontal mill from the cotton gin*

The cotton gin had two horizontal rollers that rotated in opposite directions, between which operators inserted raw cotton seeds with attached cotton fluff (see Fig. 71). The distance between the rollers could be adjusted so that the cotton seeds could not pass through the rollers and be dropped on the feeding side. In the technology that survived into the 19th century, the machines had either helical, elongated spiral worms, cog gears or no gears at all.[a]

In Volume 4, part 2 it was pointed out that the cotton gin and the sugarcane roller mill operated on the same generic technology. It was suggested, first, that they were 'the ancestors of all steel rolling mills, mangles and paper or textile machinery', second, that the cotton gin was primary, and finally that they

[a] Vol. 4, pt 2, pp. 122–4.

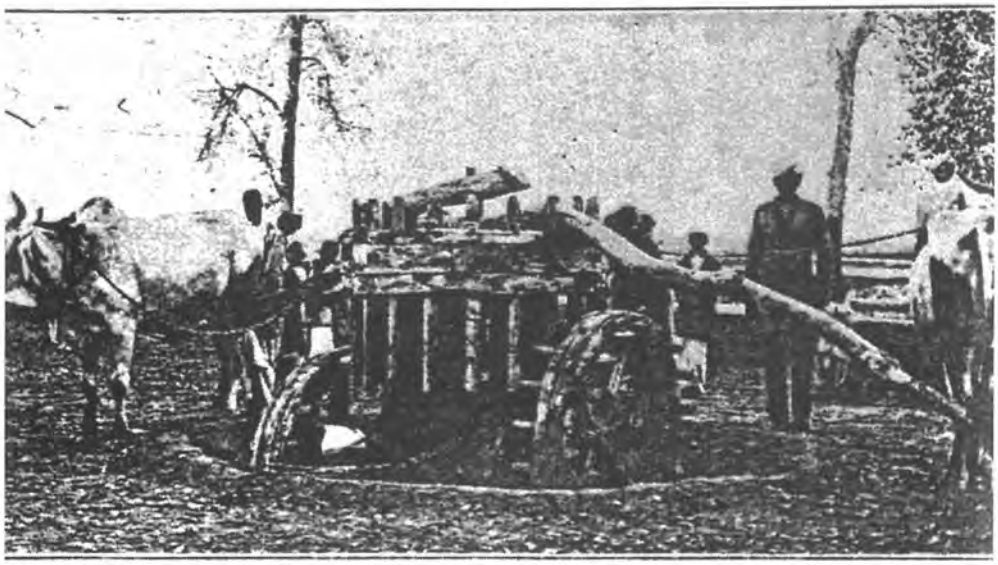


Fig. 76. A two-roller horizontal sugarcane mill with *sāqīya* gearing and parallel cogs. This is early machinery that survived into 20th-century India; Deerr (4), p. 300 and fig. 2.

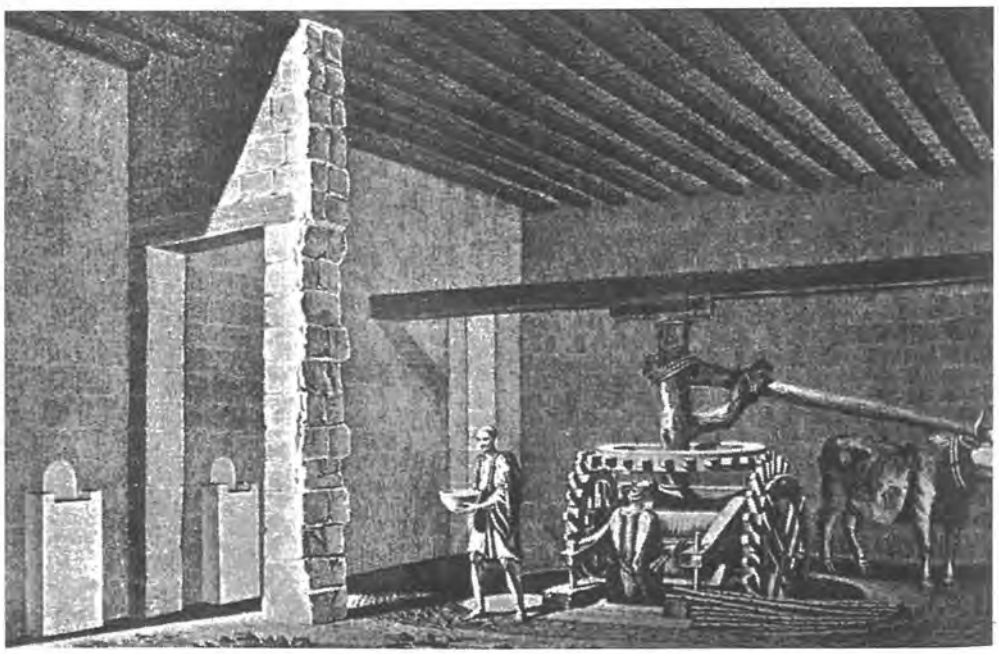


Fig. 77. A horizontal, two-roller sugarcane mill with *sāqīya* gears and radial cogs in 19th-century Egypt. This mill exhibits the solution to an inherent design problem. The different sizes of the driving wheels attached to the rollers demand that the rollers have different diameters to achieve the same surface speed. This may seem to be an insignificant design problem for a modern engineer, but was undoubtedly a challenge for a pre-modern artisan. Illustrated in the *Description de l'Egypt ... Etat moderne* I, i, pl. II; through Deerr (1), opposite p. 79.

shared joint origin in India.[a] Haudricourt & Daumas had essentially the same ideas, but regarded the sugarcane mill as primary and the likely centre of origin in the Near East. The sugarcane mills and gins they knew had cylinders linked by worm gearing. They argued that the 'existence of the screw which the Greeks were acquainted with, permits us to situate the invention of these devices in the near East in the period from the 7th to the 10th centuries, when sugarcane cultivation began to spread.'[b] Forbes has given a similar account.[c]

The occurrence of worm gearing in the machines had the opposite effect to the argument in Volume 4, pt 2 where Joseph Needham pointed to a possible origin of the worm in India rather than Greece. In addition, as the first cotton gins in China did not have gears, he concluded from this 'that on entering China the cotton gin left its worm gear behind',[d] I now believe that since there were examples of ungeared cotton gins and sugarcane roller mills in 19th-century India (see Figs. 73 and 81a), the simplest hypothesis is to suppose that the first sugarcane mills and cotton gins were ungeared when they diffused from India to China.[e]

The cotton gin evolved in India around +1100; prior to this, ginning was effected by rolling a single cylinder on cotton placed on a wooden board, and the method can be seen in a painting from Ajanta Cave No.1. The process has been illustrated in early +19th-century India (see Fig. 82). This process is characterised philologically by the Sanskrit root *luth*, which can be followed in Jain and Buddhist sources until the +12th century. The two-roller cotton gin, called the *carkhī*, appeared in Indian sources of the +12th century and dominated from that time onward.[f]

Maureen Fennell Mazzaoui found the first appearance of the cottton gin in the Mediterranean. The *manganello* or cotton gin 'is mentioned in a dowry contract of 1110 from Apulia where it was probably introduced through contacts with Sicily.'[g] This early dating in Europe poses a problem for an Asian origin if it is reliable. Daniels & Daniels have pointed out that this should be viewed with reservation as the word *mangano* of which *manganello* is the diminutive, has also been used to describe a cloth-flattening machine that consisted of a weighted box which was activated by means of cylinders built into its base.[h] This type of *manganello* could be employed to gin cotton in the fashion of a single roller.

[a] Vol. 4, pt 2, pp. 92, 204 fn. f. We use the term 'generic technology' as outlined in Fusfeld (1) to indicate the fundamental components of the technologies concerned.

[b] Haudricourt & Daumas (1), vol. 1, p. 104.

[c] Forbes (18), pp. 7–8.

[d] Vol. 4, pt 2, pp. 122 and 124 respectively.

[e] For the ungeared Chinese cotton gin see Vol. 4, pt 2, p. 123 Figs. 419 and 420. An Indian ungeared gin is shown in fig 3 in: Letter from Charles Lush to E. H. Townsend of +1835, item 112 in East India Company (2), pp. 294–7. For an ungeared horizontal two-roller sugarcane mill see Deerr (1), pl. 5.

[f] Schlingloff (1), p. 86.

[g] Mazzaoui (1), p. 74, and p. 192, fn. 1.

[h] Daniels & Daniels (4), pp. 506–7; *mangano*, Battaglia (1), p. 649.

(a)

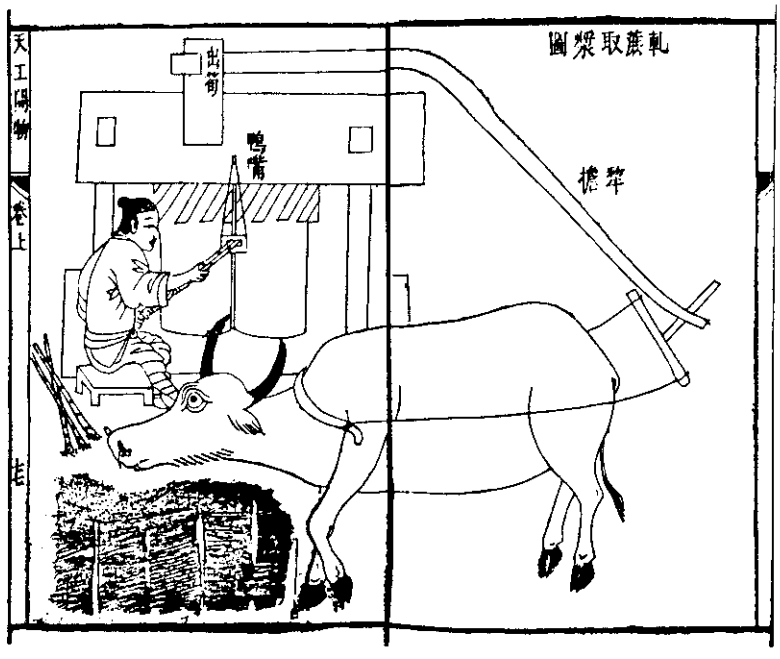


Fig. 78*a*. Figs. 78*a–c* all show the Chinese vertical double-roller sugarcane mill as illustrated in various editions of the *Thien Kung Khai Wu* of +1637. All three editions show the pressure feeder (duck's bill) in operation, but only the first two represent the gears slanted to the left. Fig. 78*a* is from the original +1637 edition held by the Seikadō Bunko in Tokyo, and is the earliest known drawing of a vertically mounted two-roller mill. Note that in the left foreground there is a pile of sugarcane which later editions have deleted, perhaps because the artists did not know what it was (courtesy of Seikadō Bunko).

(b)

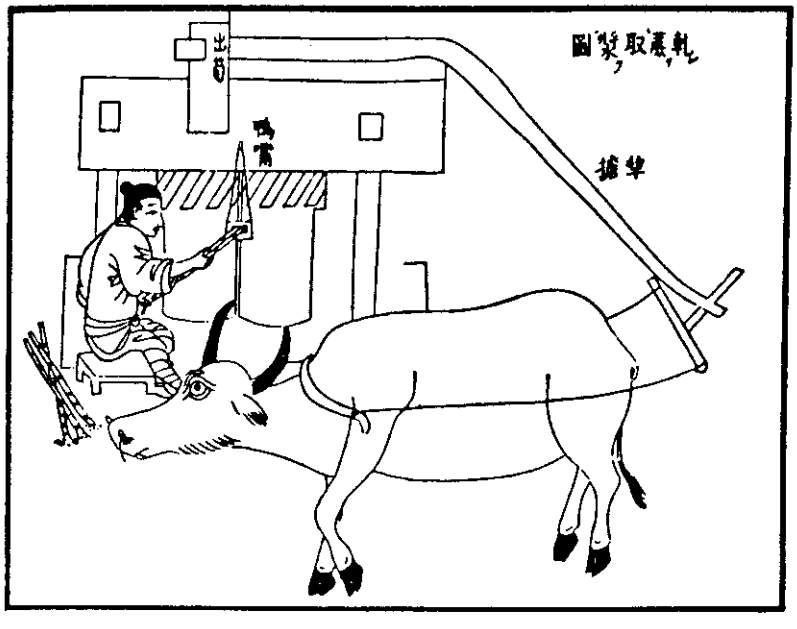


Fig. 78*b*. This is from the +1771 Japanese edition of *TKKW*. Though an accurate reproduction, its lines are not as fine as in the +1637 original.

(c)

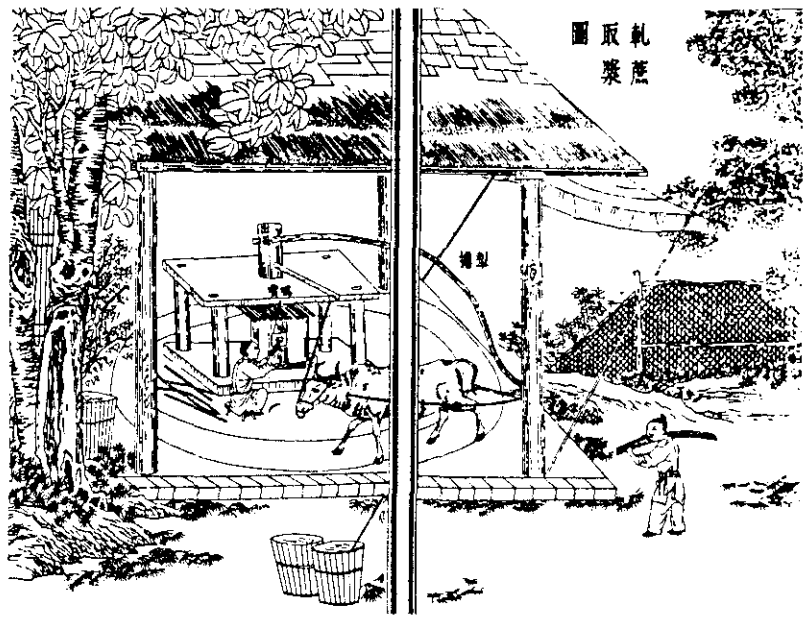


Fig. 78c. This is from a modern edition of *TKKW*, as reproduced in Vol. 4, pt 2. It is a stylised copy emphasising the surroundings rather than the technological details of the mill which has shrunk in size. For instance, it is not as easy as it is in the +1637 original to determine how the duck's bill and gears (here badly drawn and inclined to the right) were operated.

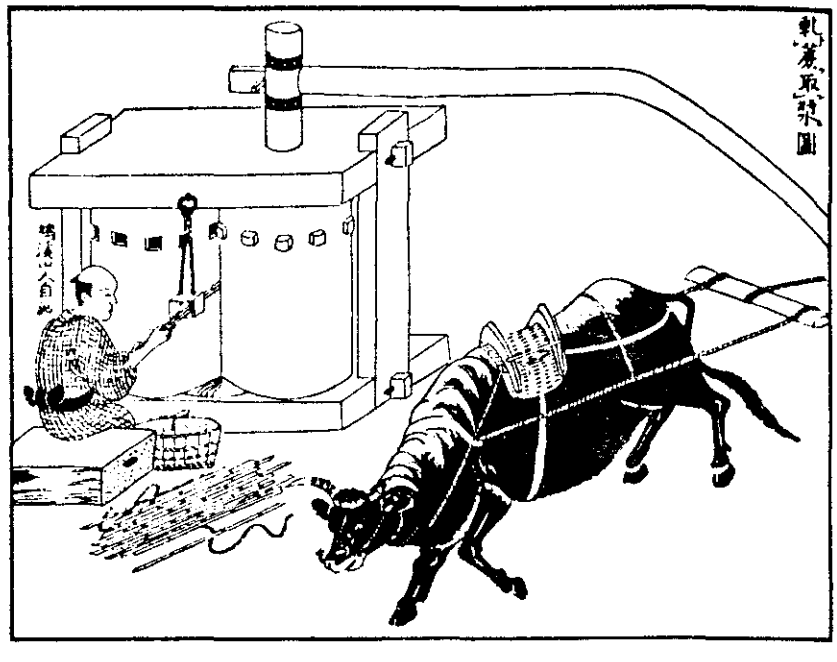


Fig. 79. The Chinese vertical double-roller sugarcane mill as drawn by Hiraga Gennai (+1728 to +1779) and included in his *Butsurui Hinshitsu* of +1763. This drawing was clearly based on the original *Thien Kung Khai Wu* illustration, but was evidently executed from personal observation as there are differences in detail; for instance, the gearing shows straight cogs and the harness is firmly attached to the oxen (courtesy of the University of Tokyo Library).

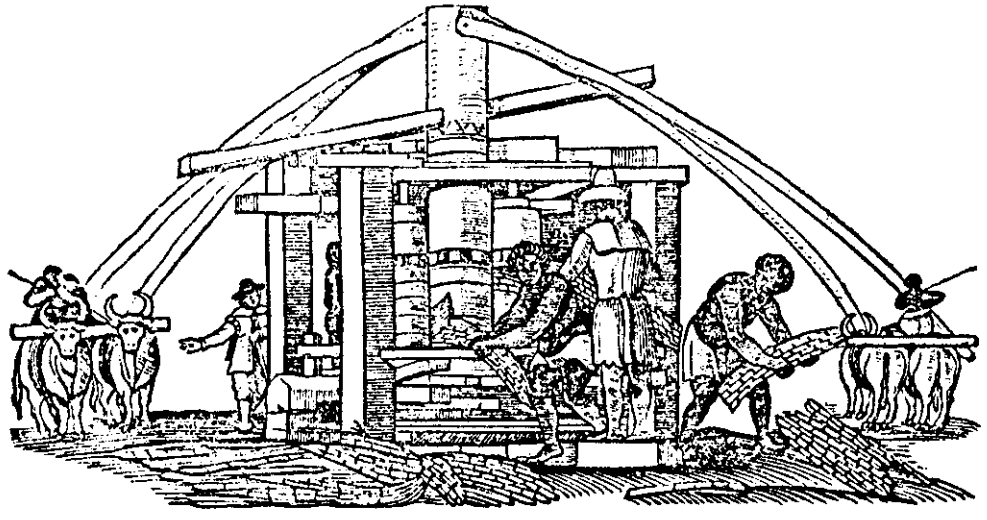


Fig. 80. A three-roller vertical sugarcane mill with cog gearing in Dutch-occupied (+1630 to +1654) north-east Brazil, +1640; illustration in *Historia Naturalis Braziliae* of Piso & Margcrav (1), p. 50.

There is well-documented early evidence for the cotton gin in China. Paul Pelliot has shown that cotton came into Fukien and Kuang-Tung from South or South-East Asia via Hainan island during the +12th century. At first, the method of ginning was exactly the same as that depicted in Fig. 82 and the Ajanta painting; it comprised a single roller disintegrating cotton on a board.[a] In +1295 or +1296 the Taoist nun Huang[1] introduced a two-roller gin into Sung-Chiang prefecture[2] in the lower Yangtse delta region from Hainan island.[b] Further documentation for this process came from Wang Chên[3] who described a two-roller ungeared cotton gin in his *Nung Shu*[4] of +1313[c] (see Fig. 71).

[a] Moule and Pelliot (1), Further Notes item 183, Cotton, pp. 425–531, see pp. 499 and 506.

[b] *Cho Kêng Lü*, ch. 24, pp. 11a–11b. The Yüan writer Wang Fêng (+1319 to +1388) gave another account of the legend in a prose poem, see the *Wu-Hsi Chi* ch. 3, p. 30b. For an account of the introduction of the cotton gin to Sung-Chiang prefecture see Nishijima (1), and refer to pp. 20–3 of the same for translations of relevant passages in the two Chinese texts mentioned above.

[c] The process was clearly described in the *Po-Chai Phien*, ch. 2, p. 5b of Fang Shao[5] (+1066 to +1141 ?) and in the *NSCY*, ch. 2, p. 19b. In these two sources it is termed an iron rod (*thieh chang*[6]). The *WCNS* pp. 415–6 recorded the first known description of the generic technology of rolling: 'In the past the turning cylinder (*chan chou*[7]) was used, and now the cotton gin (*chiao chhê*[8]), which is more convenient, is employed. The cotton gin consists of a base frame made from four pieces of wood, on top of which two small columns are erected to a height of approximately 1.5 *chhih* (0.48 m). A piece of rectangular wood is placed over the top [of the two columns]. One roller (*chou*[9]) is passed through each of the standing columns [*i.e.* one from each side], the end of the inserted roller [fitting into] but not piercing right through the opposing column. A crank-handle is attached to the protruding end of each roller [*i.e.* each roller has a crank-handle]. Two people turn the rollers while one person feeds the cotton. As the rollers rotate [in opposite directions] the seeds remain on the feeding side while the cotton passes out the other side [of the rollers]. It is several times more efficient than using the turning cylinder. Here an illustration is specially appended to make it easy for people to imitate. (Commentary [in original text]: Even though there may be a great amount of cotton, by using the present technique the seeds can be separated from the cotton without creating a back-log).'

[1] 黃道婆 [2] 松江府 [3] 王禎 [4] 農書 [5] 方勺
[6] 鐵杖 [7] 輾軸 [8] 攪車 [9] 軸

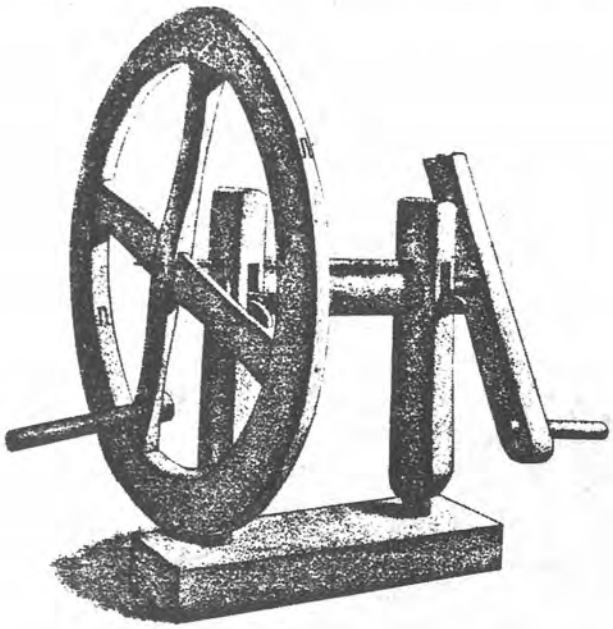


Fig. 81*a*. An ungeared cotton gin with 'fly wheel' handle from 19th-century India; East India Company (2), pl. 3.

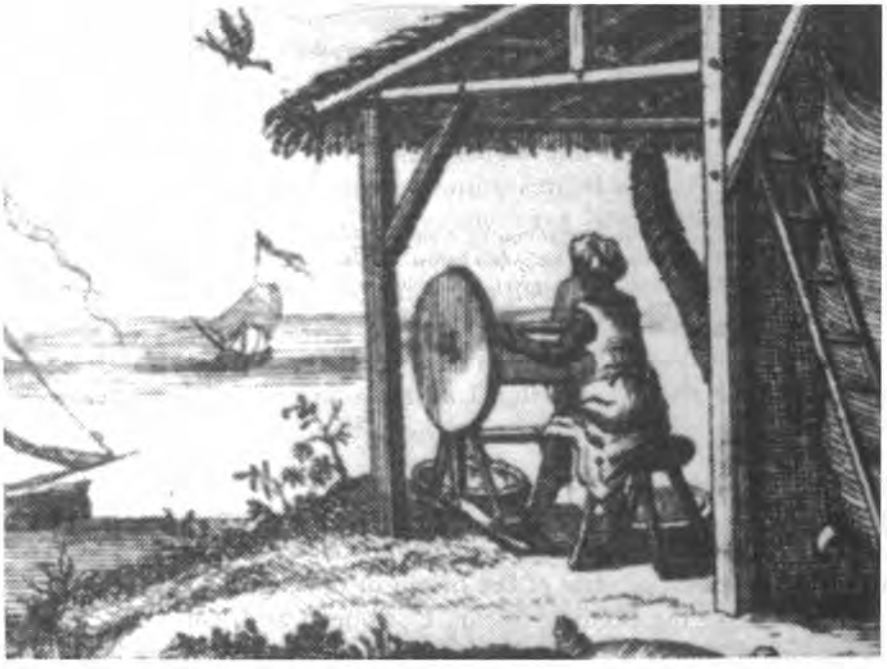


Fig. 81*b*. Cotton gin with 'fly wheel' handle used in the West Indies; detail from an illustration in Parry (1), fig. 77.



Fig. 82. A single cyclinder for ginning cotton by a simple rolling action, 19th-century India; East India Company (2), pl. 1. This technique was employed across Asia, and was first illustrated in a wall painting in Ajanta Cave no. 1 probably dating from +600, see Schlinggloff (1), pl. 4 and Rowland (1), p. 7 for dating of Ajanta caves.

These data are consistent with diffusion from a point of origin in India about the same time as the *manganello* appeared in Italy, and again poses the question of a European versus an Indian origin. Nonetheless, this problem remains academic from the point of view of the origin of the sugarcane mill as the cotton gin was present in the Mediterranean, Caribbean and Asia at the time of the development of the two-roller, horizontal sugarcane roller mill in the early +16th century.

(vi) *The development of the two-roller horizontal sugarcane mill*

The most primitive two-roller horizontal sugarcane mills were ungeared, hand-driven, and in principle scaled-up cotton gins. They persisted in northern India, from Punjab to Bengal, until the 19th century (see Fig. 73). [a] As the Punjab and Bengal are ancient sugarcane and cotton growing areas,[b] they are the most likely locations where the sugarcane roller mill evolved from the cotton gin. In these areas sugar mills had the same gears as found on *sāqīya* water- lifting machinery, and Deerr photographed a machine with parallel cogs still operating during the 1920s (see Fig. 76). These types of mills spread across north India and were only gradually replaced by vertical iron mills from about 1870. The concept spread West as far as Egypt where Napoleon's experts discovered horizontal mills with *sāqīya* gearing with radial cogs in the +18th century (see Fig. 77).

It is most difficult to arrive at a realistic date for the invention of the horizontal roller mill in India. The first firm dating of a roller mill occurred with Careri in +1695, but it must have appeared several hundred years before. Daniels & Daniels regarded +1500 as the most likely date for this innovation, and linked its widespread adoption by millers with increased demand for sugar created by the rise of the commodity market in Europe, China and India from the +16th century.[c] There is no reason why the horizontal mill could not have been developed a century or so prior to +1500 as the cotton gin is dated c. +1100. It could have maintained a low profile until the appropriate economic circumstances arose. I suggest c. +1400 in India, a date which makes it available for transfer to China on the last voyage of Chêng Ho[1] between +1431 and +1433 chronicled by Ma Huan[2]. On the first part of the voyage Ma Huan accompanied the eunuch Huang Po who led a squadron of the fleet direct from China to Bengal. They spent six months in Bengal and even sailed about 400 kilometres up the Ganges to the contemporary capital of Gaur.[d] If the horizontal roller mill was available it would surely have been discovered during this lengthy investigation and introduced to China. In China the roller mill first appeared in Fukien from which Chêng Ho squadrons usually departed. Chinese immigrants subsequently transferred this sugar mill from Fukien to the Philippines, Ryūkyū Kingdom, Japan, Taiwan and South-East Asian countries.

After examining various possibilities Daniels & Daniels concluded that the only other probable locations for an innovation from the cotton gin were in

[a] Solvyns (1), vol. 1, pl. *Sucre*; Deerr (1) pl. 5.

[b] Cotton was grown by the ancient Indus civilisations, see Allchin and Allchin (1), p. 191. Habib (1), maps 4b and 11b show the extent of cotton growing in the Punjab and Bengal about +1595.

[c] Daniels & Daniels (4), pp. 508–12.

[d] Mills (1), p. 35. Habib (1), map 11b indicates that cotton, muslin and sugarcane were produced in the vicinity of Gaur in +1595. This situation could have prevailed when Ma Huan visited.

[1] 鄭和 [2] 馬歡

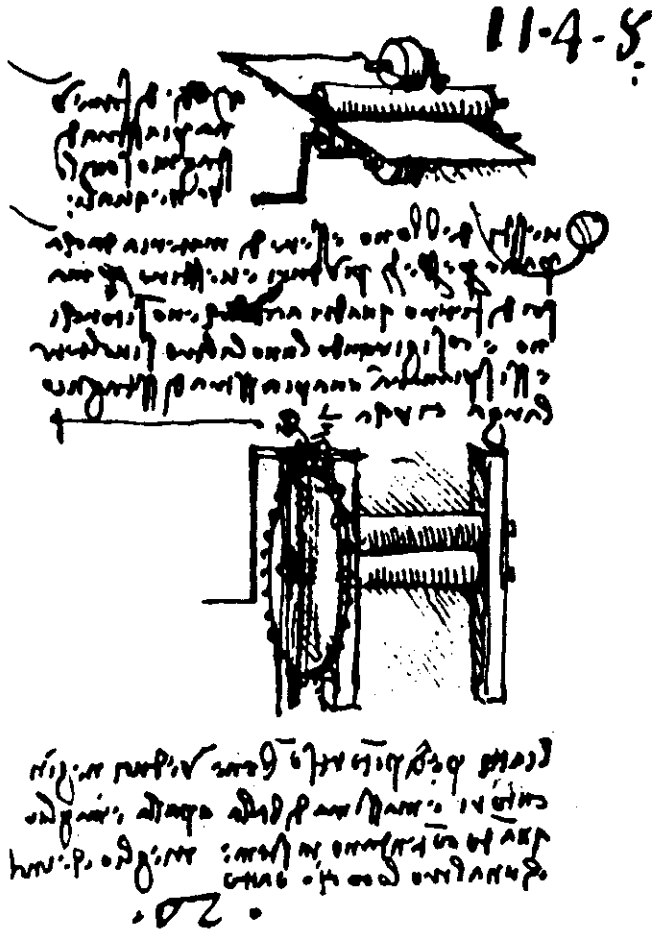


Fig. 83*a*. Two metal roller mills designed about +1497 by Leonardo da Vinci and included in his *Manoscritto I*; Uccelli (1), p. 177.

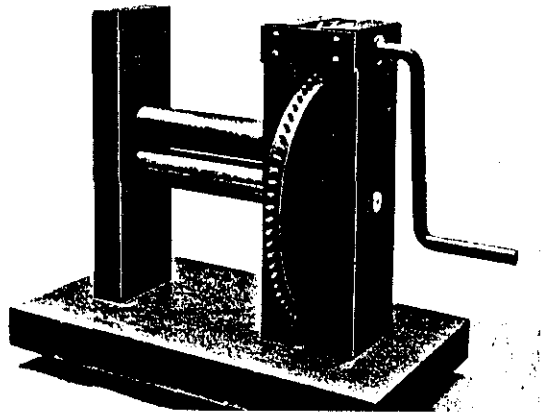


Fig. 83*b*. Photograph of a reconstruction of the lower mill in Fig. 83*a*. Similarity between cotton gins and Leonardo's construction of metal rolling mills in Figs. 83*a* and 83*b* supports the hypothesis that the cotton gin was the precursor of metal rolling mills.

Europe and the New World. The first evidence of roller milling in Europe appeared with Rudolph of Nuremberg who supposedly used miniature roller mills for making gold lace in +1471.[a] However, Leonardo da Vinci designed the first substantial roller mills in his *Manoscritto* I, about +1497.[b] Both mills, one a wide machine for rolling plate, and the other far narrower, were only powered on one roller, the other free-wheeled.[c] The similarity between Indian and New World cotton gins (Figs. 81a and 81b) and Leonardo's roller mills (Fig. 83a), especially a reconstruction of the lower mill (Fig. 83b) points to a common origin. In +1530 Giovanni Agostino Pantheo illustrated a roller mill in his *Voarchadumia* (see Fig. 84), but both rollers were independently manpowered.[d] Pantheo's mill displayed an uncanny resemblance to the cotton gin illustrated in the *Nung Shu* (see Fig. 71). Rudolph Hommel has suggested:[e]

> In Italy a ginning machine was used, probably an adaption of the 'churka' of India, which is in principle the same as the Chinese contrivance. The Italians learned the cultivation of cotton from India and call their ginning machine '*manganello*'. That sounds suspiciously like mangle ...

It is +1551 before we find geared rollers on a coinage machine set up in the Palais du Louvre which had been built in Augsberg by a jeweller, Max Schwab.[f] Germany had a tradition of iron roller milling, and it is possible that it could have been conveyed to the New World by the Welsers.

A large banking and entrepreneurial group, the Welsers, had sugar 'interests' in Madeira during the late +15th century, and set up a sugar mill in the Canaries in +1513.[g] The Welsers with their connections with coin rolling could have been an avenue for transmission if the technology was available this early. Since this mill was set up around +1513 in the Canaries it could have been taken to Hispaniola in +1515. In that year, Bachiller Gonzales de Velosa was the first person on Hispaniola to construct a *trapiche* (animal-powered mill) employing 'workmen expert in sugar' from the Canaries.[h] The following year he constructed an *ingenio* (hydraulic mill), which some authorities assert was a three-roller vertical mill.[i] Daniels & Daniels have shown this assertion to be incorrect and suggested a primitive horizontal two-roller mill instead.[j] These mills were contemporaneous with cotton gins set up to process cotton that grew naturally on the hillsides near the sugarcane-growing areas,[k] and de

[a] Hall (1), p. 45.
[b] Heydenreich, Dibner & Reti (1), p. 92.
[c] *Manoscritto* I, f. 48v, see Uccelli (1), p. 117.
[d] For a discussion of the *Voarchadumia* see Taylor (12), the illustration is given in pl. xv, fig. 1.
[e] Hommel (1), p. 162.
[f] Hocking (1), p. 68.
[g] Verlinden (1), pp. 22–3; Ortiz (1), p. 259; Fernández-Armesto (1), p. 80.
[h] Ortiz (1), p. 264. See Ortiz for a chronology of sugar in Hispaniola, which is confirmed by dates of sugar deliveries to Spain given in Deerr (1). p. 123. The Canaries were looked upon as a centre of technological expertise as late as +1569, when a *cédule royale* was issued to the *autorités des Canaries* to help establish a sugar industry on the island of Puerto Rico, see Ricard (1), p. 81.
[i] Simmonds (1), p. 156.
[j] Daniels & Daniels (4), pp. 516-17.
[k] Ortiz (1), p. 272.

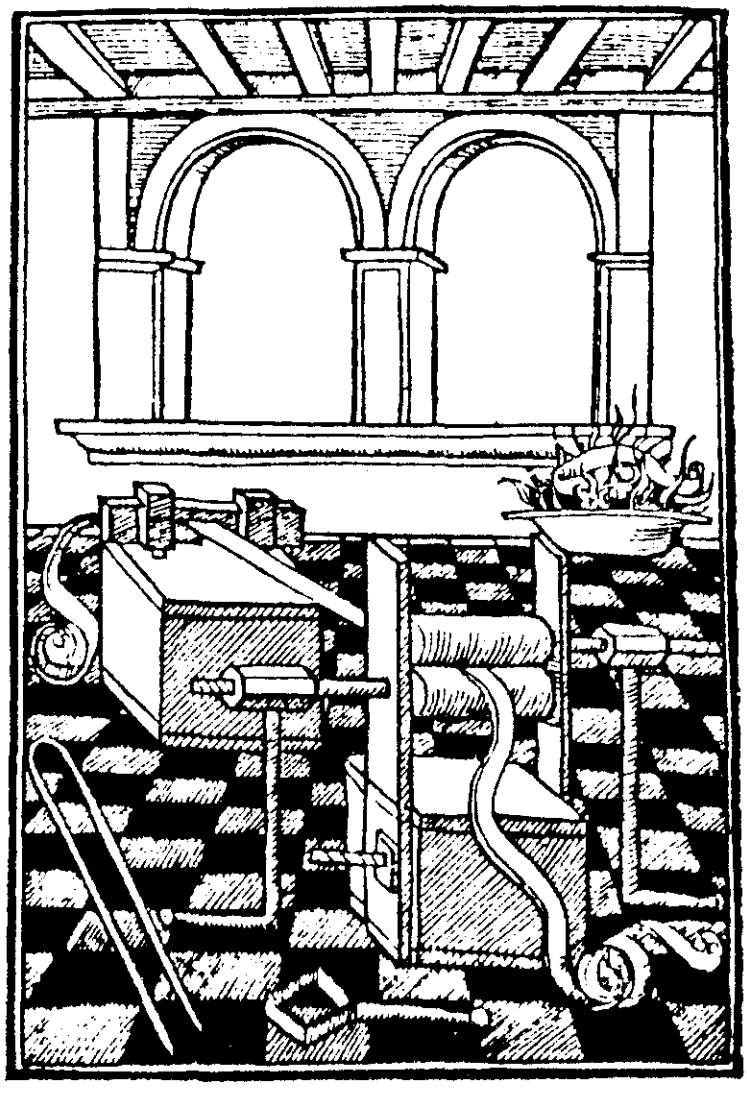


Fig. 84. An ungeared two-cyclinder metal rolling mill from the *Voarchadumia* of +1530 by Giovanni Agostino Pantheo, through Taylor (12), plate xv, fig. 1. The possible influence of cotton ginning (see Fig. 71) is apparent from this illustration.

Velosa could have adapted this *ingenio* direct from the cotton gin analogy. The Canaries and Hispaniola were likely as independent areas for an invention concurrent to India.[a] An independent primacy for India rests mainly on the ungeared simplicity of the Indian mill, that survived until the 19th century, and

[a] There is firm evidence for two-roller milling in Mexico in +1534. Rollers appeared in an inventory for a sugar mill called Tuxtla in Mexico in +1534, see Berthe (1), p. 137. The two-roller mill was also observed in the Canaries in +1570 by Francisco Hernández de Toledo, physician to Philip II of Spain, for details see Daniels & Daniels (4), fn. 72.

the opportunity for transmission from India to the New World.[a] In India the horizontal, two-roller mill was improved further than elsewhere with gearing from water-lifting machinery.

Next let us consider the feasibility of an independent Chinese origin. Alexander von Humboldt remarked in his *Political Essay on the Kingdom of New Spain*:[b]

> I am even tempted to believe that the process used by us in the making of sugar, has been brought from Oriental Asia. I recognised at Lima in Chinese paintings representing the arts and trades, cylinders placed horizontally and put in motion by a mill, cauldrons and purifying apparatus such as are now to be seen in the West Indies.

Deerr dismissed Humboldt out of hand with the curt remark, 'Humboldt saw, or believed that he saw, a Chinese vase with representations of sugar manufacture.'[c] Nevertheless, Humboldt visited the New World at precisely the time when planters were changing from the highly successful vertical roller mill back to the horizontal mill, and in the absence of concrete evidence to the contrary I see no reason to doubt the authenticity of Humboldt's observations. In fact he must be judged as one of the most careful and intelligent observers of all time.

We also possess other circumstantial evidence – Jean Nieuhovius in his *Legatio Batavica ad Magnum Tartariae Chamum Sungteium* ... of +1668 illustrated a sugarcane field with cane being processed in a shed beside which a vertical water wheel is visible (see Fig. 85).[d] Though the machinery inside the shed cannot be distinguished, the shed is so low that it is most likely a horizontal roller mill rather than a vertical roller mill, or trip-hammer installation. In addition, we have definite evidence of horizontal milling in the Sino-Amami-Japanese area (see Fig. 86). In +1717 Tabata Sabuni[1] (+1678 to +1764) harnessed water power to drive a three-roller horizontally mounted roll mill on Oshima[2], and the practice subsequently spread throughout the Amami islands[3] (see Fig. 87).[e] Kimura Yoshiyuki[4] illustrated a two-roller horizontal, hydraulic sugarcane mill in Japan in his *Satō Seisaku Ki*[5] (Notes on Sugar Making) of +1797 (see Fig. 75).[f] It is possible that there were hydraulically powered horizontal mills during the +16th century in appropriate situations in China.

One of the most likely locations was the Min river[6] in Fukien, a major sugar-producing area during the +16th century and earlier, which subsequently declined so much that it no longer grew sugarcane by the late +19th century.[g] A

[a] Daniels & Daniels (4), pp. 521–2.
[b] von Humboldt (1), vol. 3, p. 3.
[c] Deerr (1), p. 35.
[d] Nieuhof (2), p. 89.
[e] Ueno (1), p. 66.
[f] *Satō Seisaku Ki*, pp. 9b–10a.
[g] Marco Polo reported a flourishing sugar industry on the Min river near Foochow in the +13th century, see Moule and Pelliot (1), vol. 2, p. 348. This was confirmed by the *Pa Min Thung Chih*, ch. 4, p. 13b in the (*cont.*)

[1] 田畑佐文仁 [2] 大島 [3] 奄美 [4] 木村喜之 [5] 砂糖製作記
[6] 閩江



Fig. 85. A scene from a sugarcane area in +17th-century China. The shed beside the vertical water wheel in the background causes one to wonder what type of machinery was inside. I speculate that it was most likely a horizontal roller mill rather than a vertical roller mill or trip-hammer installation because of the lowness of the roof; Jean Nieuhovius in his *Legatio Batavica ad Magnum Tartariae Chamum Sungteium* of +1668, p. 89.

water mill requires an adequate water supply to be effective. In monsoon Asia, precipitation is heavily concentrated in the summer growth period, and there is a deficit during the winter when the sugarcane is crushed. This is aggravated by the fact that mills are usually run off subsidiary mountain streams, that dry up easily, and not on the more permanent main rivers which are often thirty to forty feet below field level. For example, Garnsey & Alley have published a photograph of six water mills powering hammer mills for pounding clay for making pottery in Shan-Tsang, Kao-Pho, Kuang-Tung province near the Fukien border, which harnessed water from minor hill streams, flowing into a large river below.[a] As these types of streams have seasonal flows, sugarcane processors would be very vulnerable to losing their source of power in the dry harvesting season. It is significant that Dutch paintings of large hydraulic sugarcane mills in +17th-century Brazil included subsidiary backup animal-driven

Footnotes to page 319 (*cont.*)

+15th century and Martini (2), p. 115 in the +17th century. By the 19th century sugarcane was not grown for making sugar on the Min river near Foochow, see C. Phillips' report of 1887 in Yule (1), vol. 2, p. 230. Phillips cited the fact that sugar manufacturing was absent on the Min in the 19th century, to argue that the established route taken by Marco Polo was in error. Tregear (3), map 47 (a) shows that there was no commercial production of sugarcane in the 20th century on the Min.

[a] Garnsey & Alley (1), p. 123.

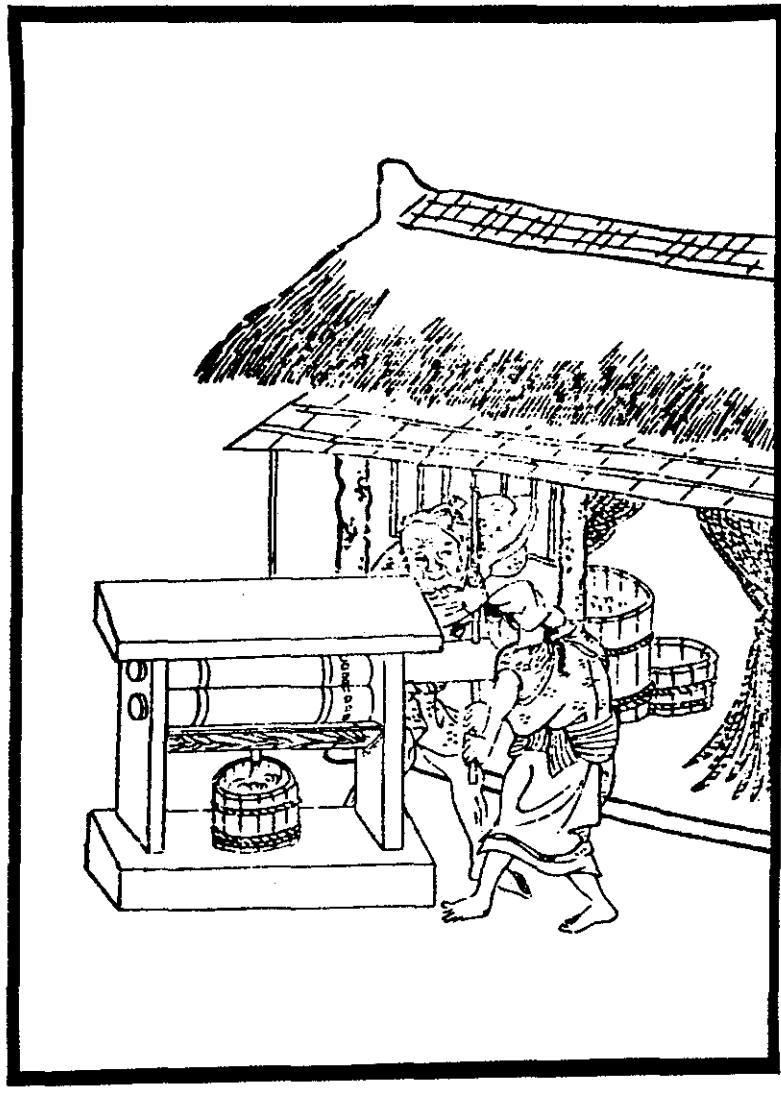


Fig. 86. A manually driven, two-roller horizontal mill in late +18th-century Japan; *Satō Seisaku Ki*, p. 17a. This gives credence to the idea that two-roller horizontal mills were present in the wider Sino-Japanese area, though there was no direct evidence from China (courtesy of the University of Tokyo Library).

mills that can be relied upon when the water supply fails.[a] Hydraulic power invariably leads to over capitalisation with additional machinery. In China, the problem of capitalisation figured less than in most countries, due to the use of portable mills that operators transported from field to field during the crushing season.[b] For the Chinese, management solutions took priority over

[a] For example see reproductions from Barleus of +1648 in Deerr (1), pl. 8.
[b] See (*b*), above, pp. 113–15.

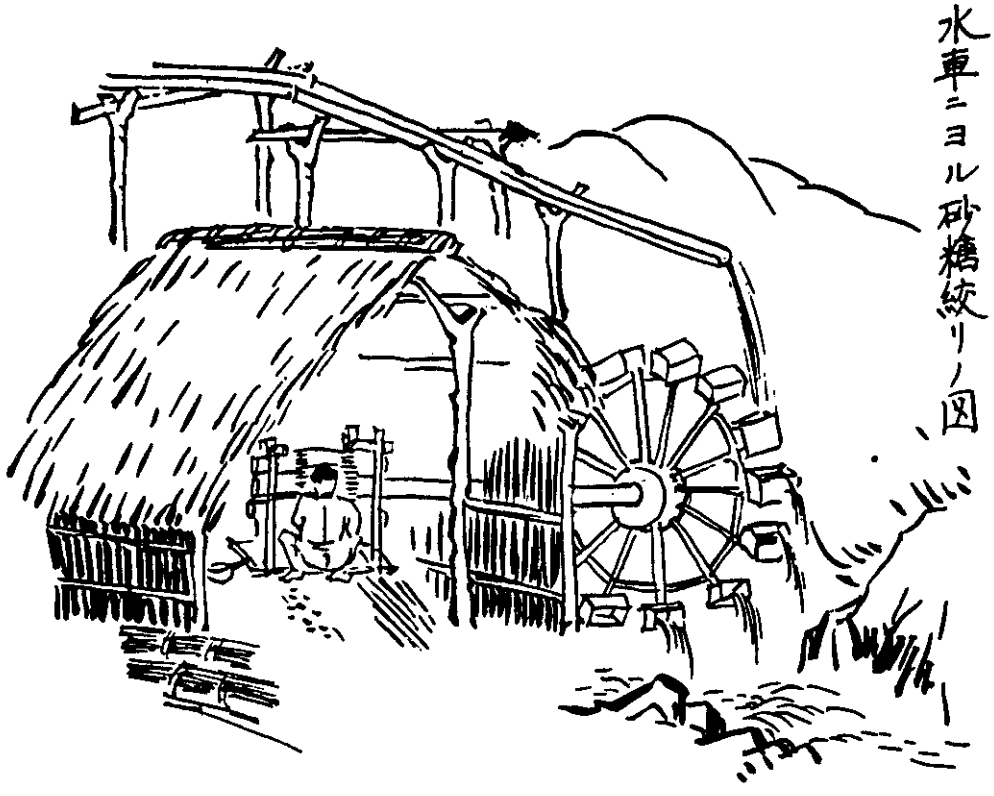


Fig. 87. Water-driven, three-roller horizontal mill on Oshima in the Amami Islands south of Japan during the 19th century. The drive axle functioned as the middle roller; Nagoya (2), p. 537.

more costly technical solutions. I shall discuss below two-roller versus three-roller vertical milling, and I shall demonstrate that the more elegant technical solution, the three-roller mill favoured in Japan, was not necessarily as economical as the Chinese two-roller mill.

(vii) *The development of the two-roller vertical mill*

The replacement of two-roller horizontal and edge-runner mills with two- and three-roller vertical mills constituted the next significant development in technology. The vertical arrangement of the rollers had significant advantages over the horizontal in primitive technology.[a] First, the gearing was far simpler, one of the rollers was elongated and driven directly, resulting in lower power requirements. The gearing of horizontal mills proved clumsy and complicated

[a] With 20th-century technology the horizontal roller mill is the usual configuration. It was pursued initially because it was more readily adapted to steam power and then it was found that it could be geared efficiently. Even animal-drive forms could be geared efficiently using bevel gearing.

leading to frequent breakdowns – compare Figs. 76 and 77 with Figs. 78a, 78b, 78c and 79. Second, the vertical alignment allowed the juice to flow away from the bagasse as it was expressed, giving potentially greater sugar recovery. With horizontal mills the juice tended to be reabsorbed into the bagasse as it exited from the rollers, and was discarded. The vertical roller mill undoubtedly rated as one of the most significant inventions in the world; it processed millions of tons of sugarcane in the New World and Asia from the +17th to the 19th centuries.

The origin of the vertical roller mill remains obscure, though India, China and the New World have all been suggested as centres of origin. Daniels & Daniels have reviewed the evidence and shown the following. First, Mazumdar's evidence for an origin of the two-roller vertical mill in India prior to +1540 was erroneous; the machine in question was a *kolhu*, an animal-driven annular mortar and pestle. Second, for the West Indies, the argument that Bachiller Gonzales de Velosa invented the three-roller vertical mill in c. +1515 on Hispaniola cannot be sustained; the earliest evidence for the three-roller vertical mill in the New World was +1613 and the two-roller mill came later. In contrast, the same authors advanced the hypotheses of a Chinese invention of the two-roller vertical mill about +1590 from an ungeared, two-roller, horizontal mill introduced from India.[a] The Chinese mounted the rollers in a vertical position because that was their normal engineering practice.[b] Subsequently we find the two-roller vertical mill transferred from China to the New World by the Jesuits where engineers constructed a three-roller version (three rollers in line) in Peru or Brazil shortly after +1600. Some New World mills illustrated in the +18th and 20th centuries bear the characteristic Chinese appearance of rollers as broad as they are high (see Figs. 88a, 88b and 88c). Daniels & Daniels also demonstrated that the Jesuits had an information gathering service with its headquarters in Rome, that collated dispatches from the New World and Asia and issued *instrucciones* to plantations in Peru, Mexico and the Philippines.[c] Their hypothesis envisaged a Jesuit transferral of the Chinese two-roller vertical mill from China to the West Coast of India around Goa. Early 19th-century reports from these areas indicated Chinese-type mills with large diameters and slanting cog gears exactly like those described in the *Thien Kung Khai Wu* of +1637. Chinese mills are readily distinguished from Indian mills by their cylinder diameters c. 24 versus c. 8 inches respectively. Indian engineers then adapted the mill by substituting parallel worm gearing for slanting cogs. This worm-geared mill with cylinders c. 8 inches in diameter then spread over cen-

[a] Daniels & Daniels (4), pp. 523–4.

[b] The Chinese preference for vertical alignments has been discussed in Vol. 4, pt 2, p. 546. See also White (5), pp. 515–26.

[c] The first *instrucciones* issued by the Society's General in Rome have been lost, see Chevalier (1), p. 246. Later *instrucciones* are available but they are not strong on technical information; for Mexico see Chevalier (2); for Peru, Macera (1), for the Philippines, Costa (1), p. 116.

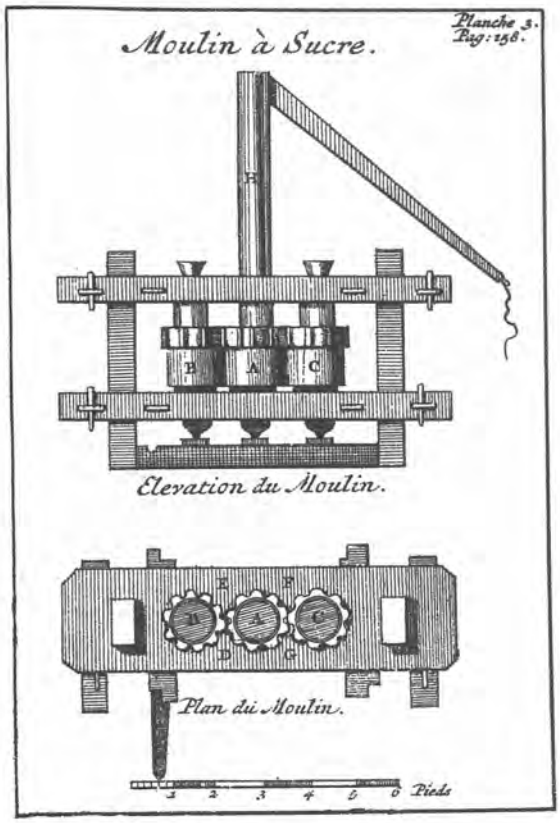


Fig. 88*a*. Three-roller vertical mill from the French Antilles in the early +18th century; de Quélus (1), of +1719, pl. 3 opposite p. 158. Notice that the roller diameter is about the same size as the roller length. This was a characteristic feature of Chinese sugarcane roller mills.

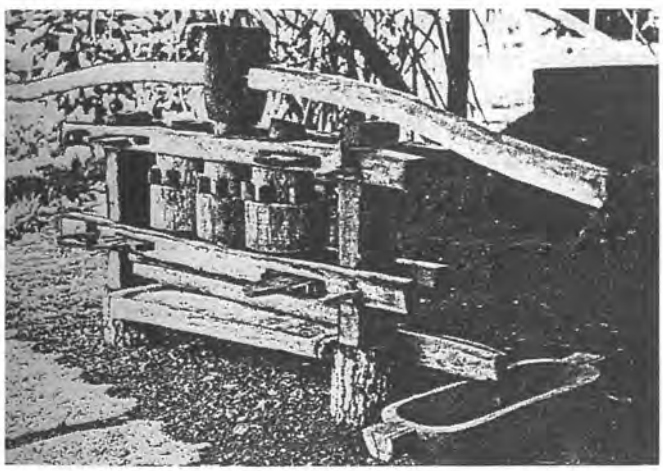


Fig. 88*b*. Three-roller vertical mill from Cauca valley, Columbia; Córdoba Zuloaga (1), p. 16. This mill is obviously related to the French mill in Fig. 88*a*. The Chinese characteristic of having rollers as broad as they are long supports the hypothesis of influence from China.

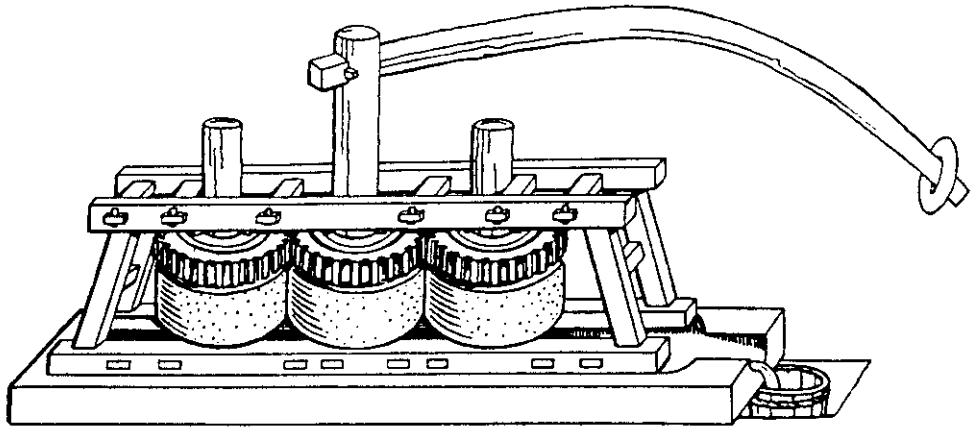


Fig. 88*c*. Drawing of a three-roller vertical mill held by the Miki Bunko, Tokushima Prefecture, Japan, in the 20th century; orig. photo Christian Daniels. This mill has a wooden gear collar attached to the stone rollers beneath. This type of mill also appeared in 19th-century Java, and displays the typical Chinese characteristic of the roller being as broad as it was high.

tral and south India[a] and overseas. It was recorded as far west as Mozambique, another Jesuit stronghold, and as far east as Sumatra and Thailand (see Figs. 89a, 89b and 89c).[b] We are now in a position to examine India, China and the New World afresh.

Let us begin with the vertical roller mill in China. Above we suggested that it could have evolved from an ungeared horizontal mill possibly introduced from India by a squadron from Chêng Ho's seventh and last voyage that returned to China in +1433. They stayed in Bengal for six months prior to joining the main fleet at Calicut on the outward voyage.[c] The roller mill gained popularity in China only far later, when higher crushing rates became necessary to meet the greater market demand for sugar generated by the expansion of the money economy, and the need for bagasse as fuel arose due to deforestation. The

[a] These worm gears have been discussed in some detail in Vol. 4, pt 2, pp. 119–24; the origin of the use of parallel worm gears remains obscure, but seems to be centred in India. Hugh Kerr Thomas has published on the theory of worm gears (Thomas (1)). Apart from Bengal, the Indian vertical worm-geared mill did not penetrate north India. The reason for the difference of horizontal in the north, versus vertical configurations in central and south India, probably derived from differences in water-lifting machinery. In the north the same village carpenters built water-lifting machinery and sugar mills. They used the same *sāqīya* gearing in both machines; they only had one generic technology in their repertoire, see Watt (1), vol. 6, pt 2, p. 304. This resulted in horizontal sugarcane mills, the only way the *sāqīya* gears can be used. In central and south India irrigation was effected by lifting water from wells using a large skin bucket pulled up by animal power, or flooding from rivers, see Watt (1), vol. 6, pt 2, pp. 205, 216, 239. The village carpenters would not have vested interests in any particular gearing and used the more mechanically efficient vertical mill. The history of terminology of irrigation equipment in India is discussed in detail in Gopal (2), pp. 114–68. Gopal has followed the terminology given in Vol. 4, pt 2, p. 356, where the *sāqīya* is a pot-chain pump and the noria has a peripheral pot wheel, see Schiøler (4), p. 15 for a different, more complex classification based mainly on shaft length; noria short, *sāqīya* long. We have adopted Schiøler's classification of gear cogs into parallel (long thin cogs at right angles to the driving wheel and *parallel* to the shaft, see Schiøler (4), fig. 22) and radial (cogs projecting *radially* from the wheel, see Schiøler (4), fig. 23).

[b] Marsden (1), p. 188.

[c] Mills (1), p. 35.

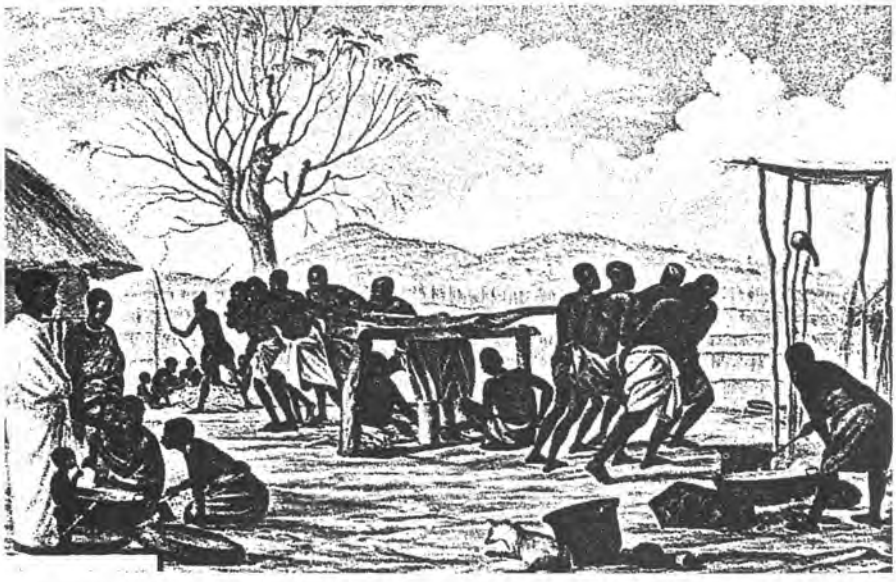


Fig. 89*a*. A painting by Thomas Baines (+1822 to +1875) of a two-roller vertical mill with parallel worm gearing in 19th-century Mozambique. This mill was invented in India and is distributed from Mozambique through central and southern India and as far East as Sumatra and Thailand; Royal Botanic Gardens, Kew, through Baxa & Buhns (1), between pp. 288 and 289.

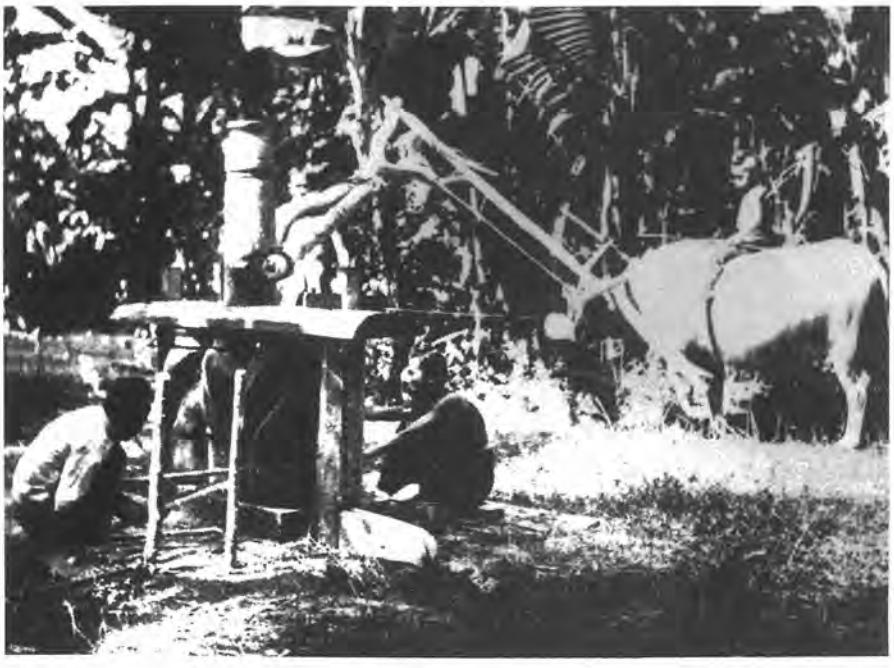


Fig. 89*b*. A three-roller vertical sugarcane mill with parallel worm gearing in early 20th-century Thailand; Graham, W. A. (1), opposite p. 318. Thailand and Sumatra were the furthest extent East of the parallel worm geared mills invented in India.



Fig. 89*c*. Chevron gearing on a water-driven horizontal double-roller sugar mill at Man-Hai Village[1], Meng-Lung Chen[2], Ching-Hung county[3], Sip Song Panna (Hsi-Shuang Pan-Na[4]) in Yunnan, January 1990. Dai people[5] carve four chevron gears on each wooden roller, and this gearing is invariably longer than the crushing part of the roller. In this photograph the gearing part is 73 cm long (gear diameter 27 cm), while the rest of the roller within the frame only measures 67 cm (diameter 21 cm). For a detailed report of this gearing see Daniels (*7*). Until recently, the Dai people of Sip Song Panna extensively employed chevron gears on both animal- and human-powered vertical roller mills, in addition to the type shown in this photograph. Apart from the Dai people of Sip Song Panna, I know of no other instance of chevron gearing on sugarcane crushing machinery; orig. photo Christian Daniels.

two-roller vertical mill appeared in two forms in China. The earliest known reference to the first form appeared overseas in the Philippines in an early Spanish-Tagalog vocabulary, *Vocabulario De Lengua Tagala*, of +1613 by Father Fray Pedro de San Buenaventura,[a] and the first detailed description accompanied by an illustration occurred in the *Thien Kung Khai Wu* (see Fig. 78a):[b]

To construct the vertically mounted double-roller mill (*thang chê*[6]) take two wooden boards measuring five *chhih*[7] (1.6 m) long, five *tshun*[8] (16 cm) thick, and two *chhih* (64 cm) wide. Holes are bored at the end of each board to stabilise the supporting posts. The upper ends of the posts protrude a little bit above the upper board, while their lower ends extend two or three *chhih* [64 to 96 cm] below the lower board and are buried in

[a] Buenaventura (1), p. 420. For a full translation of this reference see, (*f*), below, pp. 419–20.
[b] *TKKW* p. 167. Cf. Sun & Sun (1), p. 126.

[1] 曼海村 [2] 勐籠鎮 [3] 景洪縣 [4] 西雙版納 [5] 傣族
[6] 糖車 [7] 尺 [8] 寸

the ground to anchor [the whole apparatus]. At the centre of the upper board two openings are constructed, through which two large rollers (*chou*[1]) made of very hard wood, are positioned one next to the other. It would be best to have the wooden rollers measuring seven *chhih* [2.24 m] in circumference. One of the rollers measures three *chhih* [96 cm] in length while the other measures four and a half *chhih* [1.44 m]. The end of the longer roller protrudes out and is affixed to the sweep (*li tan*[2]) which is a curved pole made of bent wood fifteen *chhih* [4.80 m] long.

[The rollers are turned by] an oxen that pulls the sweep in a circle. Intermeshing male and female cogs are carved on the sides of both rollers (*chou shang tso chhih fên phei tshu hsiung*[3]). The part where the cogs interlock is straight and round, they must be rounded to interlock (*chhi ho fêng chhu hsü chih êrh yüan yüan êrh fêng ho*[4]).

Sugarcane is crushed by inserting it between the [ungeared part of] the two rollers. [This machine which separates juice from cane fibre] by crushing operates on the same principle as the cotton gin [which separates seeds from cotton fibre].[a] Juice flows off [the rollers] as the sugarcane is crushed. The first bagasse is crushed a second time by feeding it into the rollers through the duck's bill (*ya tsui*[5]). A third crushing extracts all the juice. The bagasse is used as fuel.

Bore a hole in the lower board to hold the rollers. The hole should be only 1.5 *tshun* [4.8 cm] not deep enough to allow the rollers to pierce through the board, thereby facilitating accumulation of juice on its surface. Iron ingot bearings (*thieh ting*[6]) are inlaid into the centre of the bottom end of each roller to expedite rotation. The [extracted] cane juice flows into a jar through a trough (*tshao chien*[7]) on the board.

This account is so complete that it would be possible to construct a machine by referring to the illustration, a most unusual thing for Chinese works on technology. The text also specifically stated: 'It would be best to have the rollers measuring seven *chhih* [2.24 m] in circumference', indicating that this was a recently perfected invention in which there had been some experimentation on the dimensions of the components. Mazumdar has pointed out a problem with the gearing as illustrated:[b]

> The gear teeth at the top of the rollers are of the single helical sort, but are inaccurately depicted in the illustration – the rollers would not have revolved if the cogs had been placed as illustrated.

She has redrawn the mill with standard helical gears intermeshing from opposite directions.[c] Mazumdar is in error as a Chinese wooden mill photographed in operation in the Philippines during the 19th century (Fig. 90a) clearly indicated slanting cogs that intermesh from the same direction as is shown in the *Thien Kung Khai Wu* (Fig. 78a). Additional evidence appeared in a mill photo-

[a] The statement that the roller mill operated on the same principle as the cotton gin may indicate that contemporaries thought the vertically mounted two-roller sugarcane mill derived from the cotton gin, and that my postulation of an origin from an ungeared sugarcane mill from India is mistaken.

[b] Mazumdar (1), p. 106

[c] *Ibid.*, p. 109.

[1] 軸 [2] 犁擔 [3] 軸上鑿齒分配雌雄
[4] 其合縫處須直而圓圓而縫合 [5] 鴨嘴 [6] 鐵錠 [7] 槽槽



Fig. 90*a*. A two-roller vertical mill from Iloilo, the Philippines, in the 19th century. Note the slanting cogs engaging from the same direction; Sonza (1), opposite p. 32.

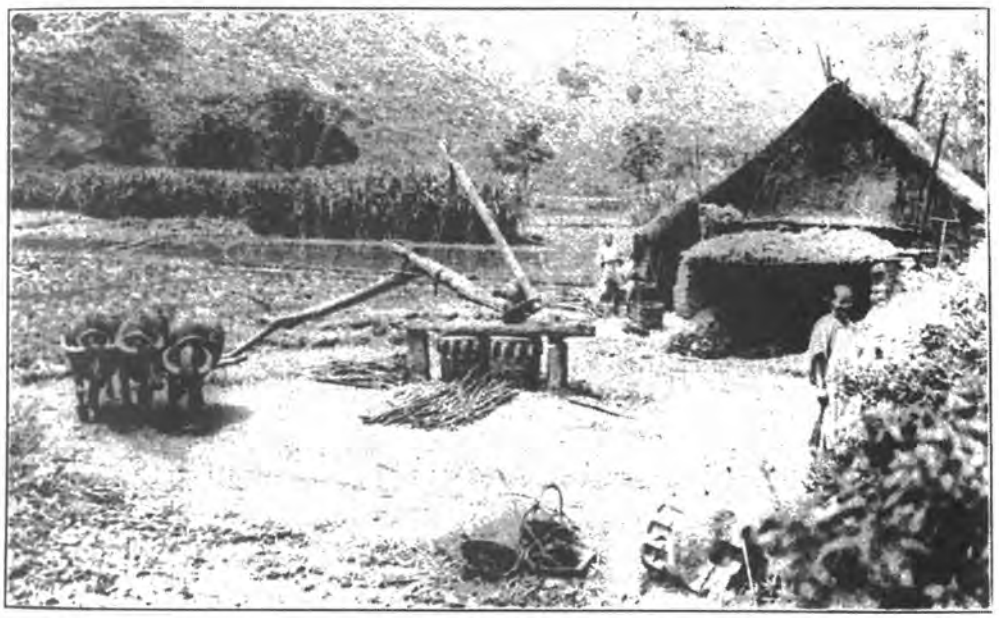


Fig. 90*b*. Chinese *mo*[1] type sugarcane mill with slanted cog gears at Amoy during the early 20th century; Pitcher (1), between pp. 48 and 49. Figs. 90*a* and 90*b* prove that the contention in Mazumdar (1) that the gearing illustrated in the *Thien Kung Khai Wu* of +1637 (Fig. 78a) was misdrawn for helical gears is clearly incorrect. These operational machines show gearing with slanted cogs.

[1] 磨

graphed at Amoy during the early 20th century (see Fig. 90b). Furthermore, helical gearing was not a part of traditional Chinese engineering in medieval and modern times, and no helical device appeared in East Asia until the introduction of the Archimedes pump into the Sado[1] gold mines in Japan during the mid +17th century.[a] On the basis of this evidence I conclude that the gears illustrated in the *Thien Kung Khai Wu* were slanted and not helical.[b]

Apart from the wooden roller mill the Chinese also had a stone mill which was probably contemporary with the *Thien Kung Khai Wu*, though the first literary evidence only appeared in the Japanese papers recording interviews with Chinese merchants at Nagasaki[2] in +1726, who called it a *shih-chhê*[3] or literally stone roller.[c] The stone cylinders were nearly as broad as they were high, and greatly resemble those of the Chinese grain mill (*mo*[4]). With the *mo*, the grain was fed down a hole in the stone and ground on the base, in the case of multiple mills two or more *mo*s were geared together with cog gears attached to the tops of the millstones.[d] Two *mo*s geared tightly together effectively formed a vertical sugarcane mill (Fig. 90b), and as noted earlier this similarity appears to have given the word *mo* the meaning of stone roller in some instances. The stone roller mill was a unique Chinese development and Chinese immigrants transferred it overseas.[e]

In India, as stated above, there were mills on the west coast near Goa with atypically large diameter cylinders and slanting cog gears. A Chinese origin via the Jesuits is the simplest explanation because Indian mills have far smaller diameters (c. 8 inches).[f] I suggest that the worm-geared vertical mills with normal Indian-sized cylinders (c. 8 inches), found over central and south India, were adaptions made to the introduced mill by Indian engineers.

The two-roller vertical mill is poorly documented in the New World. The three-roller mill appeared first in a manuscript drawing deposited in the Ajuda palace and dated +1613. The two-roller mill must have been present before this but it is +1649 before we find a record in Richard Flecknoe's *A Relation of Ten*

[a] White (16), p. 238 & Demizu (1), p. 16.

[b] In addition White remarked that 'helical gearing early reached India but did not cross the Himalayas. No helical device has been found in East Asia until the so-called Archimedes screws appeared in Japanese mines in the seventeenth century, presumably introduced by Portuguese or Spanish engineers'. (White (16), p. 238.)

[c] Ōba (1), pp. 321–3.

[d] See Vol. 4, pt 2, p. 196, Fig. 451 for an illustration from the *Nung Shu*[5] which shows an animal-driven milling plant (*lien mo*[6]) with eight mills powered from a central whim wheel by cog gears. These mills date back to at least the +4th century, see Vol. 4, pt 2, p. 195.

[e] In a later version of this mill in Java and Japan the gears were separately attached to the top of the stones. For examples of such gearing in Java, see Dodds (1), fig. on p. 2; for Japan, *Satō Seisaku Ki*, pp. 5b–6a, Ota (1), p. 465; for Hawaii, Baxa and Bruhns (1), p. 258. I have observed such gearing on a mill in Japan in the possession of Mr Okada Hidehiko[7], a manufacturer of traditional sugar products in Kamiitachō[8], Itanogun[9], Tokushima[10] prefecture (see Fig. 88c).

[f] Later in the 19th century a mill with true helical gearing was recorded in the same area, see Albertini and Gollwitzer (1), fig. 13, p. 55, which gives the source as Lopes Mendes *A India Portuguesa*, Lisbon, 1886.

[1] 佐渡島 [2] 長崎 [3] 石車 [4] 磨 [5] 農書
[6] 連磨 [7] 岡田英彦 [8] 上板町 [9] 板野郡 [10] 徳島縣

Years Travells in Europe, Asia, Affrique and America when he visited Rio de Janeiro:[a]

> ... the mill, turned by oxen, or water, consisting of two round cylinders, about the bigness of millposts, plated with iron, which turning inwards, and joining as close together as they can meet, so squeeze the canes passing through them.

In addition, two-roller vertical mills are described by César de Rochefort in +1658 and William Hughes in +1672,[b] both of whom toured the Caribbean. Sauer observed vertical two-roller mills on his travels through 20th-century Latin America.[c] It is necessary to stress this point because in reading authorities such as Deerr (1) you would believe that the two-roller vertical mill never reached the New World.

The question now arises as to whether China or the New World has priority for the two-roller vertical mill. This problem is not likely to be solved easily. Daniels & Daniels have pointed out that with the efficient information gathering services of the Jesuits and their ability to obtain results in practice, any innovations would disperse so rapidly that without specific documentation it would be most difficult to assign priorities.[d] However, we believe that the appearance of the earliest documentary evidence for the Chinese two-roller vertical sugarmill in the Philippines in +1613, twenty-four years prior to the first Chinese source of +1637, indicates its presence in China, or more precisely Fukien during the second half of the +16th century; it must have been there for the Chinese to have taken it overseas. Therefore there must have been every opportunity for transfer through the Augustinian and Jesuit systems from either China or the Philippines. For example, the Augustinian Martin de Rada went with Miguel Lopez de Legaspi from Mexico to found the Spanish colony of the Philippines in +1564. De Rada set about collecting all the information he could about China from the considerable Chinese population in the Philippines, and had several Chinese books translated. In +1575 he was amongst a party of four that went on a mission to Fukien province, one of the major sugar-manufacturing areas in China at the time. De Rada sent a report, books and papers to the court of Philip II and briefed his friends in Mexico, and this established lines of contact which continued into the +17th century.[e] The Jesuits commanded even better sources, for they had a continuous supply of information from China from the time of Melchior Nunes Barreto, who spent ten months along the southeastern Chinese coast from +1555 to +1556. Numerous missionaries made visits from this time until Matteo Ricci who resided in south China from +1583 until the mid +1590s.[f]

In short, channels for a transfer from China to the New World definitely ex-

[a] Through Boxer (3), p. 234.
[b] de Rochefort (1), p. 313; Hughes (1), p. 32.
[c] Sauer (2), p. 210.
[d] Daniels & Daniels (4).
[e] Lach (1), vol. 1, pp. 746, 749, 778, and 806.
[f] *Ibid.*, p. 796 for Melchior Nunes Barreto, and pp. 794–815 for Jesuit writings and Matteo Ricci.

isted. What reasons do we have for believing that this is the case? First, if the Jesuits introduced the vertical roller mill from the New World or elsewhere it would have been documented. Their publicity machine aimed to stress the value of European science and technology in endeavouring to gain a foothold to evangelise in China. Second, the time scale is short for an invention in the New World about +1600, and its transfer to China and export to the Philippines as a piece of Chinese machinery prior to +1613. Third, if the vertical roller mill diffused from a point in the New World to China one way and to Europe in the other, there should be evidence of vertical milling in Europe. In Spain, in constant contact with the Spanish colonies, the vertical mill did not appear in Francis Willughby's account of the sugar industry in Spain in +1664 which only recorded edge-runner and hydraulic horizontal mills.[a] Until further information becomes available, an origin of the vertical mill in China remains the simplest hypothesis. The evidence concerning the New World deriving from the Ajuda manuscript and the *Historia* of Brother Vincentes indicated an infiltration via Peru. The Jesuits erected an animal-driven mill *trapiche* at Surco in Peru near Lima as early as +1581.[b] This may have been the first vertical mill in the New World, and derived from a Chinese source.

(viii) *The origin of the vertical three-roller mill*

The English-speaking world until recently has accepted as dogma that Pietro Speciale invented the three-roller sugarcane mill in Sicily in +1449. Soares Pereira demonstrated in 1955 that this dogma, formulated by von Lippmann in the first edition of *Geschichte des Zuckers* published in 1890, was clearly incorrect, and that the *trappeto* of Speciale was an edge-runner and not a three-roller mill.[c] Yet, the controversy has continued because of the general ignorance amongst English-speaking scholars of Soares Pereira's work and subsequent discussion in French and Portuguese studies by such scholars as Jean-Pierre Berthe and Gil de Methodio Maranhão. In 1977, J. H. Galloway alerted the English-speaking world to the problem, but such is the prestige of von Lippmann and Deerr who independently arrived at a Sicilian origin, that the origin remained a controversy until the study by Daniels & Daniels.[d] I have mentioned earlier the possible origin of the two-roller horizontal mill in the Canaries and the New World. Several historians have confused the situation by claiming that the second mill that Gonzales de Velosa built on Hispaniola in +1516 was a three-roller mill.[e] No evidence exists for the three-roller vertical mill until about +1613, when it appeared in a manuscript illustration deposited in the Ajuda

[a] Ray, John (1), pp. 477–9.
[b] Martin (1), p. 173.
[c] Soares Pereira (1); von Lippmam (4), (1890 ed.) p. 217.
[d] See Berthe (1); Methodio Maranhão (1); Galloway (1); Daniels & Daniels (4).
[e] Simmonds (1), p. 156.

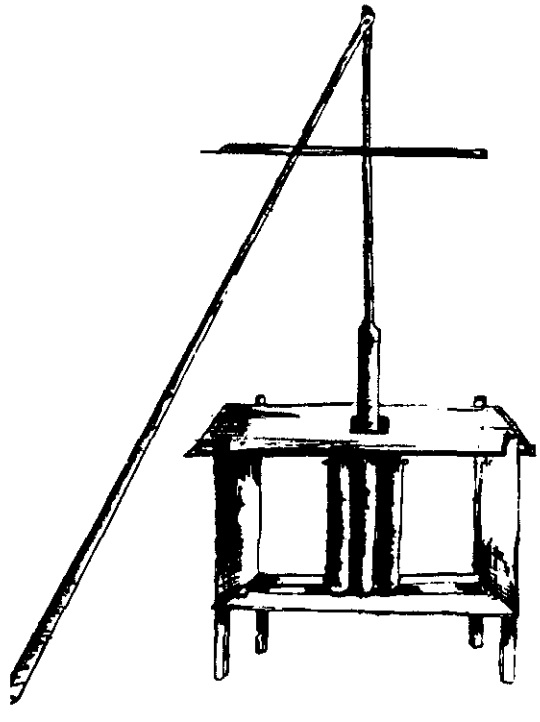


Fig. 91. A manuscript illustration of a three-roller, vertical mill, deposited in the Ajuda Palace, Portugal, and dated +1613. This is the earliest illustration of a three-roller mill in the world. All three-roller mills were collinear until the late +18th century; Mauro (1), pl. III, between pp. 203 and 204.

Palace dated +1613 (see Fig. 91).[a] The illustration depicts a three-roller mill invented in Peru and introduced to Brazil by a Spanish priest. Brother Rodrigues Palha Vincente do Salvadore related the same story as the Ajuda manuscript in his *Historia do Brasil* of +1627; the Spanish priest introduced it from Peru in the time of Diogo de Menzies (+1508 to +1612).[b] In +1620 a Portuguese colonist, Gaspar Lopes Coelho, in a petition to the Crown, claimed to be the inventor of the three-roller vertical mill in Brazil.[c] Whatever the truth of these conflicting reports, it is obvious that the three-roller vertical mill must have been a recent invention, c. +1600, for Coelho to have plausibly asserted his claim.[d]

[a] Mauro (1), pl. 3.

[b] Vincente (1), p. 333. Galloway ((3), p. 339) reviewed the Peruvian origin and in a footnote on p. 349 floated the idea 'that the home of this mill may not be Peru but China'. Galloway ((4), p. 207), followed this up by claiming evidence for three-roller milling in China on the basis of an illustration in Baxa & Bruhns (1), p. 218, which is recorded there as a mill operating in late 19th-century China. Unfortunately, the illustration in Baxa & Bruhns (1) derives from Hawks (1), and represents milling from 19th-century Ryūkyū (Okinawa), as recorded on the Perry expedition to Japan and elsewhere.

[c] *Archivo General de Simancas, Secretarias Provinciales* 1473, fols. 38–39v. I am grateful to Amandio Represa, Director of the Archives, for providing a photocopy of the document and to Professor Ikuta Shigeru of Daitō Bunka University, Tokyo for translating it.

[d] Barros de Castro ((1), pp. 700–1) has advanced an hypothesis reconciling the two conflicting origins. He suggests that the Spanish priest was familiar with mining technology and gave the concept of the vertical mill

(*cont.*)

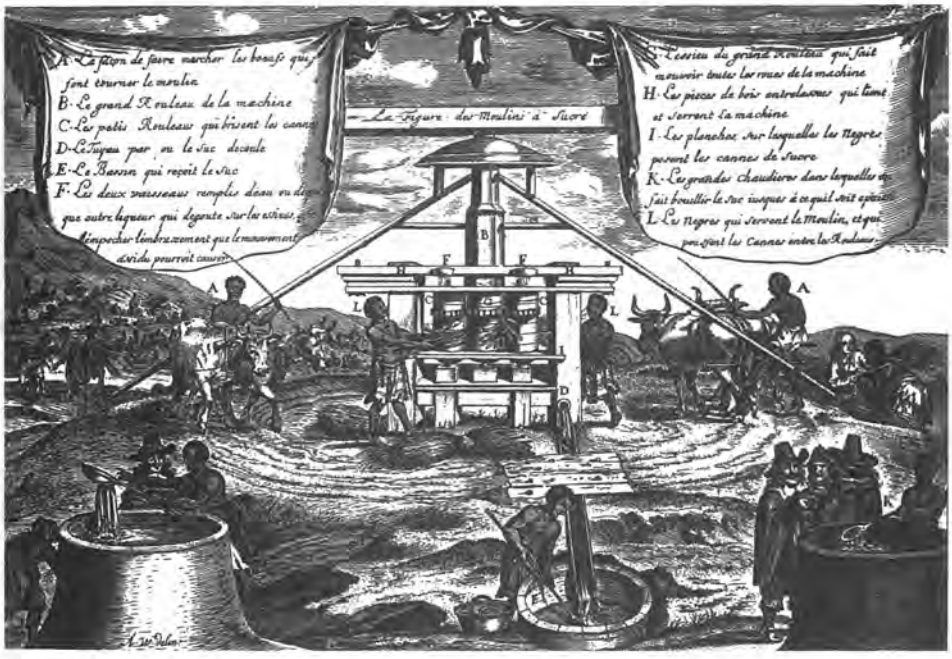


Fig. 92*a*. An animal-driven three-roller vertical sugarcane mill in the +17th-century French Antilles; Rochefort (1), through Baxa & Bruhns (1), p. 35.

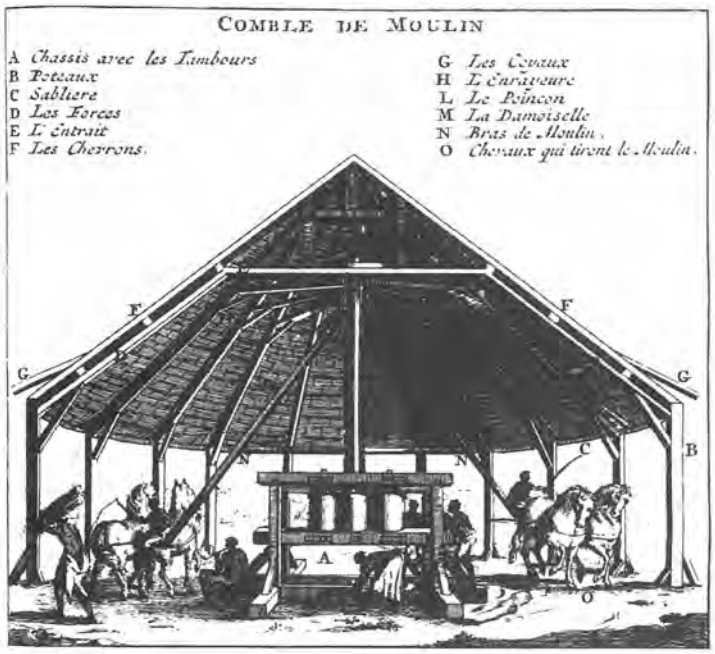


Fig. 92*b*. A three-roller vertical sugarcane mill in late +17th-century Martinique. Compare with Fig. 92*a*, and note the extra sophistication in the framework which has provision for tightening the rollers; Labat (1), vol. 1, opposite p. 258.

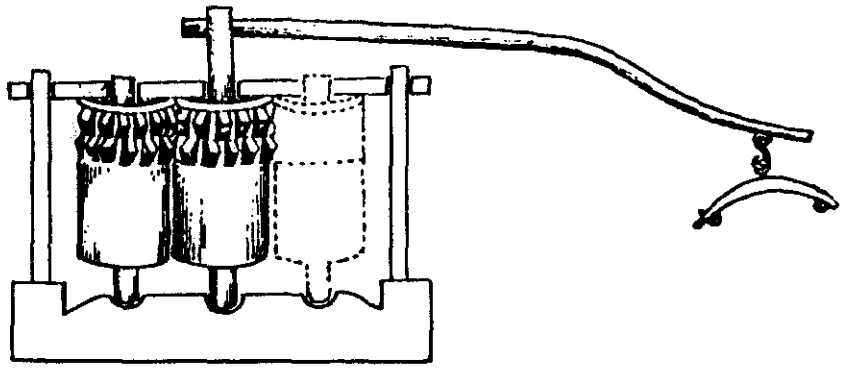


Fig. 93. A two- to three-roller mill from 20th-century Indochina. Note the gearing. There was a great range of gearing in Chinese-influenced East Asia; Lan (1), pt 2, pl. 2, between pp. 182 and 183.

From this time onwards three-roller mills became the focus of attention in the New World, most planters adopted them, and César de Rochefort in his *Histoire Naturelle et Morale des Iles Antilles de l'Amérique* of +1665 and Father Jean Baptiste Labat in his *Nouveau Voyage aux Isles de l'Amérique* of +1722 illustrated them dramatically (see Figs. 92a and 92b). Though the three-roller vertical mill was never recorded in China, yet we find it in areas which borrowed sugar technology from China such as the Ryūkyū and Amami Islands, Japan, the Philippines and Vietnam (see Fig. 93) at varying periods. It seems most unlikely that the Chinese did not know of their existence.

Why were there no three-roller vertical and water-powered mills in China? Mazumdar emphasised the decentralised smallholder economy and demand factors:[a]

The sugar industry in China, however, remained a part of the decentralised small holder economy, and this combined with the seasonal nature of production, affected the type of technology used. The capital outlays involved in establishing more efficient means of production such as water powered cane crushers [and three-roller mills] were not carried out because demand never expanded to the point of necessitating a more extensive production schedule. The manner in which international demand was translated into the local economy therefore becomes a crucial variable, for as long as the demand remained more or less constant, the demand could be met by operating several tens of less efficient cane crushers. Only when a sudden and major increase occurred in this demand, did it become crucial to find the means of increasing the effi-

Footnotes to page 333 (*cont.*)

to Coelho. Coelho, an experienced engineer, then constructed the sugarcane mill. An examination of the source for mining technology (Bakewell (1), p. 20 and fig. 2) cited in the latest work of Barros de Castro indicates beyond doubt that mining *ingenios* were water-driven stamping mills of a different generic technology. There is no reason to believe that mining machinery could present any useful ideas for the construction of a vertical roller sugarcane mill. Daniels & Daniels (4) suggested alternatively that if Coelho had anything to do with the mill, he invented a three-roller version of a vertical two-roller mill that had been imported from China via Peru and the Spanish priest. It is logical that two-roller mills preceded three-roller versions, and two-roller mills persisted into the 20th century in Spanish America, see Sauer (2), p. 210, fn. 21.

[a] Mazumdar (1), p. 126.

ciency of the machinery, for under such circumstances those who did not innovate would face a loss in revenues.

Wider evidence for Chinese sugar-making technology does not support this hypothesis of a simple demand factor.[a] Two major sugar-producing regions in South-East Asia employing Chinese technology – Java and the Philippines – operated on a volume orientated basis after the +18th century, but did not use three-roller mills. They persisted with two-roller, vertical stone mills until the mid-19th century. Even during the late 19th century when Chinese sugar enjoyed great demand on the international market, attempts to change to newer more 'efficient' iron mills all ended in failure.[b] It is plain that the Chinese considered a number of two-roller mill batteries more effective than three-roller mills.

The nature of the three-roller mill has never been analysed critically by historians of technology, presumably because the obvious advantage of being able to feed back the bagasse from the other side of the mill, has concealed the inefficient aspects of this operation. It was often implied that the three-roller mill possessed twice the rate of the double-roller mill. This was clearly an exaggeration as the second back pass of sugarcane in the three-roller mill remained underloaded due to the juice extracted in the first pass. Experimental work on small iron roller vertical mills in late 19th-century India also indicated that three-roller mills operated only marginally faster than two-roller mills.[c] These qualifications, however, do not deny the fact that one turning of the rollers in a three-roller mill extracted greater quantities of juice than a two-roller mill. Yet, it should be realised that other factors made the two-roller mill far easier to manage. First, it required less animal power to drive the rollers. The three-roller mill has so much more friction to overcome in wooden configurations that it cannot be driven by one animal, a most important feature for China where a dearth of draught animals prevailed from the +16th to the 20th century.[d] Second, transportation of the whole mill proved easier because of the lightness of the two-roller mill.

The case for not utilising water power, again suggests good management rather than the pursuit of technology as a primary objective. Efficient use of water mills depended on two main factors, topograpy and sufficient water supply; both had to be adequate during the crushing season and, needless to say, such conditions were relatively rare. For example, utilisation of hydraulic mills varied greatly among the West Indies colonies from a few to about 60 per cent

[a] Also the concept that a decentralised smallholder economy consituted *a priori* a factor limiting the adoption of three-roller mills is suspect because they also found use in other countries such as India, where production was rooted in a basically similar type of smallholder economy as in China.

[b] Myers (1), pp. 17–18.

[c] Watt (1), vol. 6 pt 2, p. 277.

[d] Campbell (1), vol. 2, p. 913 indicated that two roller Chinese mills in Java were driven by one water buffalo, or at most two, while in the West Indies relays of four horses were employed at the same time for a similar size mill. For the dearth of draft animals in China see *SCC* 6(2), pp. 3–7, p. 8(d) & p. 311.

of all mills.[a] The sugarcane areas in south China away from the deltas often have steep banks thirty to forty feet high, clearly not suitable topography for sugarcane water mills. Though delta areas enjoyed an adequate supply of water, the pressure of flow often proved insufficient to drive mills. Water mills are best driven from swiftly flowing streams, as can be seen from an illustration of six water-wheels powering hammer mills for processing clay in potteries in Shang-Tsang, Kao-Pho, Kuang-Tung; here the mills are powered by minor hill streams flowing into a large river below with very high banks.[b] Since these types of streams have seasonal flows, and as sugarcane is harvested in the dry winter season, sugarcane processors depending on hydraulic power would be very vulnerable to long delays due to lack of water power. It is significant that, as we have remarked previously, Dutch paintings of large hydraulic sugarcane mills in +17th-century Brazil invariably show back-up animal mills. Hydraulic and wind sugarcane mills led to potential over capitalisation; to maintain continuity of harvest, animal back-up still remained necessary. Chinese operators effected further economies in capital by using portable animal-driven roller mills that could service a number of cane fields. I reiterate a point made earlier that, for the Chinese, management solutions took priority over more costly technical solutions.

Returning to the question of the three-roller mill, we should not forget that the generic technology of activating machinery components with complex gearing was well known in China where up to eight grain mills (*mo*) driven from the same whim wheel were illustrated in the +14th century.[c] At our present stage of knowledge we cannot rule out a transmission of a three-roller concept originating in China. More research is necessary to clarify conflicting claims in Peru and Brazil.

In summary, the simplest hypothesis for vertical milling is that the sugarcane mill was introduced in a two-roller horizontal form from India to China, where gears were added and a vertical mode of roller mounting adopted. Towards the end of the +16th century the vertical milling concept was conveyed to the New World, where engineers devised two- and three-roller mills within a short time of each other. The two-roller geared form probably went from China to India in the +17th century. We will now examine the rise of the roller mill and try to determine how efficiently it functioned in practice.

(ix) *The rise of roller mills, their outputs and efficiencies*

For understanding the rise of the roller mill it is important to realise that, contrary to numerous assertions, it did not extract a higher percentage of juice than

[a] Ragatz (1), p. 61.

[b] Garnsey and Alley (1), p. 123.

[c] See the illustration of a geared, animal-driven, grain milling plant (*lien mo*) with eight mills from the *Nung Shu* in Vol. 4, pt 2, p. 196, Fig. 451. This is a very ancient machine invented in the +3rd century in China, see Vol. 4, pt 2, p. 195.

other machinery. The extraction rate (c. 65 per cent at the best) in fact rated far lower than the diffusion methods (c. 90 per cent) and marginally lower than the *kolhu* and the edge-runner with secondary pressing (c. 70 per cent).[a] The virtue of the roller mill was that it could crush larger amounts of sugarcane in a shorter time. Perhaps poorer extraction had a beneficial effect, because partial extraction gave higher juice purity which led to faster boiling rates and better crystallisation. In addition, the roller mill needed less labour as the cane could be fed directly into the roller without the need for chopping it first, as required for former methods. Whole stalk feeding also resulted in crushed stalks that could be immediately used to fuel the boilers, an exceedingly important measure for lowering costs, which finally must have become vital as deforestation proceeded.[b] Charles Gustavus Eckeberg in the +1740s and the French traveller Chréton Joseph de Guines in the late +18th century observed the use of bagasse and cane leaves as fuel in inland Kuang-Tung province, as did the Reverend John Scarth for Swatow in the +19th century, thus confirming the earlier account of the *Thien Kung Khai Wu*.[c] In fact whole stalk feeding was probably the deciding factor in the roller mill gaining ascendency, as pulp bagasse from hammer and edge-runner mills made poor fuel and proved difficult to handle.

Unless properly adjusted two- and three-roller mills only yielded 50 per cent extraction or less. Surprisingly this poor efficiency passed unnoticed by Asian and European colonial engineers until the early 19th century. Interest became evident in experimentation with multi-roller mills which appeared first on Oshima, in the Amami Islands south of Japan with Kashiwa Yūto[1] in +1818. He experimented with five- and seven-roller mills made of iron, but apparently retained a three-roller mill for crushing to meet the extortionate demands of Satsuma Han[2].[d] This research came several years ahead of a British patent No. 8731 of 1840 for a six-roller mill granted to James Robinson acting for unnamed parties in Mauritius and Réunion.[e] The real extent of loss due to poor

[a] During the 19th century technicians conducted a large number of trials comparing diffusion with roller milling. In India Kohn ((1), p. 273) obtained 85% for diffusion versus 60% for roller milling; in Louisiana Spencer ((1), pp. 52 and 61) reported 93% for diffusion versus 72% for roller milling; and in Demerara in British Guinea J. Owen Alexander ((1), p. 633) reported 85% for diffusion versus 67% for roller milling. See Daniels & Daniels (4), pp. 512 and 524 fn. 111 for extraction efficiencies of the *kolhu* and edge-runner with secondary pressing.

[b] The cost of operations and the effect on deforestation can be gauged by a report that in colonial Brazil eight cartloads of well sorted firewood were needed to process eighteen to twenty loads of cane, see Schwartz (1), p. 118

[c] Osbeck (1), p. 297; de Guignes (1), vol. 1, p. 265; and Scarth (1), p. 49. Osbeck described a portable diffusion method which consisted of a wooden roller (*kun nien*[3]) for breaking the cane with subsequent boiling of bagasse in water. The bagasse was able to be used as fuel after drying because whole stalk feeding was possible with the *kun nien*. The *Kansha Ki*[4] of +1764 by Gotō Rishun[5], a manuscript recording Japanese experiments with the sugar-making techniques the Japanese learnt from China, explained how to feed bagasse into furnaces; 'place the frass of crushed sugarcane stalks beside [the furnace]. When the fire is thought to be a little too strong add the crushed stalks to weaken the fire' (no pagination). Here we see the stoking of bagasse to regulate the force of the fire.

[d] Shō (1), pp. 292–3.

[e] Deerr (1), p. 544.

[1] 柏有度 [2] 薩摩藩 [3] 轟碾 [4] 甘蔗記 [5] 後藤梨春

extraction was only exposed with the invention of the polariscope by Jean Baptiste Biot in 1840 to measure sucrose concentration in solutions.[a] The polariscope depends on the fact that sucrose in aqueous solution rotates the plane of polarised light in proportion to its concentration. Manager–technicians employed it extensively in the emerging beet sugar industry, and then in sugarcane factories to measure losses.

20th-century engineers in Pakistan and South America have confirmed the poor extraction of c. 50 per cent from animal- and machine-driven vertical roller mills. They also examined the factors influencing rates in terms of the amount of juice extracted,[b] and found that roller diameter has no significant effect on extraction, and that the most significant variables were fibre percentage of sugarcane, roller speed and adjustment of spacing between rollers. With animal-driven machines roller speeds become slow and near optimum for extraction. Regarding the other two factors, lower fibre clones of sugarcane yield higher extraction (variation from 10 per cent to 14 per cent fibre causes 5 per cent loss in extraction),[c] and more careful erection of machines with continual attention to roller spacing proved advantageous (a 5 per cent increase was possible with optimum settings). As far as I am aware there have not been any studies on the attributes of animal-driven mills that effect rates. However, an examination of the illustrations of vertical roller mills in Figs. 78a, 78b, 78c and 79 indicates that the connection between the following two variables is important in the design of a roller mill for optimising crushing rate:

1 The diameter of the roller
2 The length of the sweep.

It is assumed that the opening between the rollers will be kept as small as possible, and that the driving force in terms of animals is optimised by trial and error. The initial design for rate is influenced most by roller diameter versus the length of the sweep. I suggest that after the transfer of the roller mill from India to China engineers optimised its dimensions by experimentation leading to a three- to four-fold increase in rate. This was accomplished by increasing the diameter of the rollers from 8 inches in India to about 24 inches in China, along with changes in the length of the sweep from 8 feet to 12–16 feet.[d] From 1872, the Indian government promoted the vertical two-roller iron mill of 8 inches diameter rolls and a sweep of 8 feet. It registered rates of about 100 lb per hour which yielded about the same as the machines it replaced. But extraction was assessed at about 10 per cent greater, and because of lower friction it could

[a] Browne and Zerban (1), p. 145.

[b] Force, Bokhari, Ali, Shaukat & Eshan (1); Garcia, Abarca, and Moreno (1).

[c] The *S. sinense* and *S. barberi* clones have a higher fibre content than *S. officinarum* and this would lead to greater loss of sucrose in the bagasse than in tropical countries cultivating the *S. officinarum*.

[d] Indian mills varied from 5.25 inches to 12 inches in diameter, see Blechynden (1), p. 580; Watt (1), vol. 6, pt 2, p. 307, though most mills were around 8 inches, see Watt (1), vol. 6, pt 2, pp. 196, 237, 269, and 278. See Table 14 for dimensions of Chinese mills.

Table 14. *Extraction and production rates of Chinese two roller vertical sugar mills in Chinese influenced Asia*

Location	Diameter rollers (in Eng. inches)	Sweep length (in Eng. feet)	Extraction juice % cane	Rate lbs/hour
China[a]	27	14	—	—
Taiwan[b]	25	—	50	356–532
Japan[c]	24	15	70	497
Burma[d]	24	12	57	460

[a] *TKKW*, p. 167.
[b] Myers (1), pp. 16–17.
[c] Ota (1), pp. 465–6. This case from Japan referred to a three-roller vertical mill.
[d] Watt (1), vol. 6, pt 2 pp. 248–9; Barber (6), p. 395 demonstrated that the roller mills in Burma were of Chinese origin.

be powered by fewer animals or men. In addition there was less loss of time due to breakage.[a] These findings are a convenient yardstick with which to assess the Chinese achievement. Though there are no extraction and rate data available for China itself, information is available for mills in the Chinese cultural area. It is assembled in Table 14.

Dimensions of overseas Chinese mills displayed remarkable similarity to those first described in the *Thien Kung Khai Wu* of +1637. The rates ranged in the order of three to four times that of the Indian mill, but the extraction of juice remained much the same at about 50 per cent. When we turn to the New World we find that although the mill dimensions measured about the same as the Chinese (20 to 25 inches diameter with an 18 feet sweep),[b] the rates at about one ton per hour were five to six times higher than that of the Chinese in the late +17th century.[c] By the 19th century mills achieved four tons of cane per hour with about 50 per cent extraction in the Caribbean.[d] This large increase in rate in the Caribbean was primarily due to the amount of animal power applied. Bryan Edwards in his celebrated work of +1793 discussed production rates and commented that rates as high as three to four tons of cane per hour were achieved with eight mules, the fastest animals; but this was not the norm, rates were usually lower. Edwards thought 'the lower rates to rest more with the mill-wright than with the machine'.[e] I suggest that the large increase in rates in

[a] For dating and discursive assessment see Birch (1), pp. 526–7, for data see Watt (1), vol. 6, pt 2, pp. 196, 278.
[b] Porter (1), pp. 141–3. These are average figures by Porter. But there was considerable variation. Labat (1), vol. 2, p. 242, reported 15 inches to 18 inches for animal-driven mills in Martinique in +1696, while Antonil (1), p. 175, fn. 23, spoke of 29 inches to 34 inches for water driven mills in Brazil in +1693.
[c] Barrett ((2), p. 157), listed data available for rates from the +16th to the +19th centuries. There was no data available for extraction.
[d] Barrett (*Ibid.*) summarised data available for the 19th-century Caribbean with the comment, 'It seems reasonable to accept an extraction rate of fifty per cent for the vertical mill, irrespective of the nature of the drive.'
[e] Edwards (1), vol. 2, pp. 228–9 fn. (b).

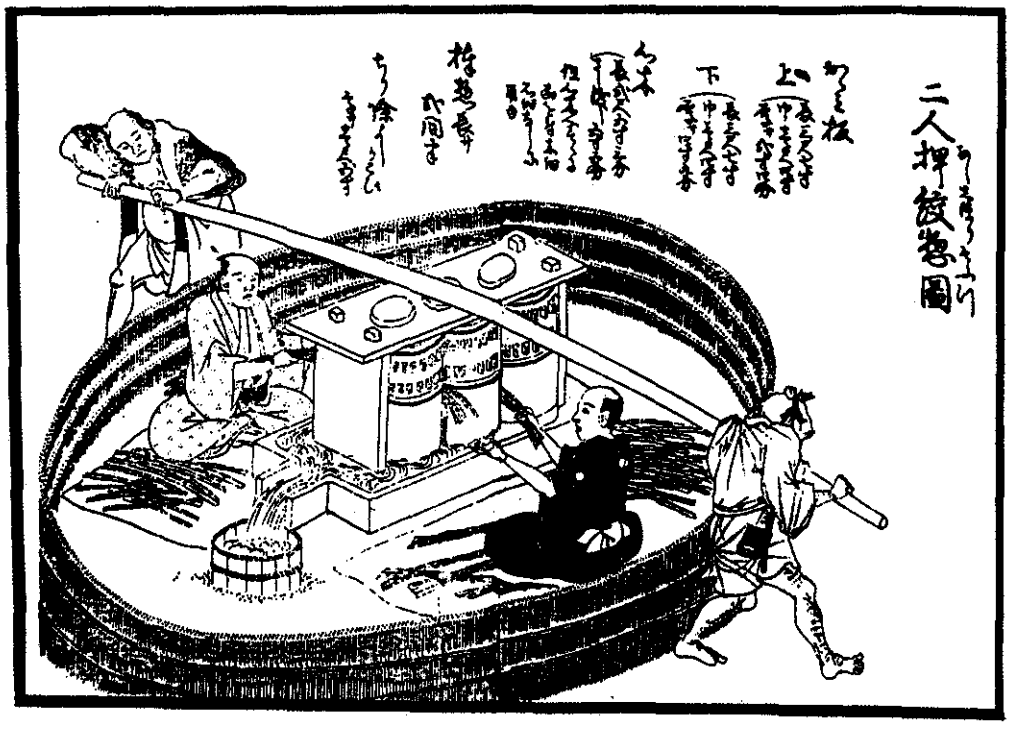


Fig. 94. A manually driven three-roller sugarcane mill in late +18th-century Japan. This is one of the few illustrations depicting the operators feeding the mill from either side, which is the cardinal advantage of the three-roller mill; *Satō Seisaku Ki*, pp. 7b–8a. The inscription at the top gives the measurements of the mill. The rollers, with the gear cogs attached, were completely made of wood, and measured 16.5 cm in diameter and 76 cm in height. Another illustration in the *Satō Seisaku Ki*, pp. 5b–6a, showed a vertical, three-roller stone mill (roller diameter 45 cm and roller height 26 cm) with wooden cogs separately attached (gear apparatus had diameter of 42 cm and height of 24 cm), that was powered by four men. Perhaps more power was needed to turn the stone rollers rather than the wooden ones. Katsura ((*1*), pp. 58–60) suggested that the man dressed in the black crested kimono feeding sugarcane into the rollers was Sugarmaster Sanzaemon[1], the technological founder of sugar manufacture in Kishū[2] (courtesy of the University of Tokyo Library).

the New World resulted from two factors: first, the number of animals applied (only one to three in China versus up to eight in the Caribbean) and second, the fact that planters in the Caribbean used the three-roller mill in preference to the two-roller mill.

(x) *Chinese managerial expertise versus technological solutions*

Chinese experience contrasts significantly with that of the Ryūkyūans and Japanese who pursued technical development rather than management solutions. A Ryūkyūan engineer independently designed a three-roller vertical mill in +1671.[a] From there it went to the Amami islands and the Japanese mainland where it soon appeared in a variety of forms including manually driven and

[a] *Kyūyō* (*1*), p. 232.

[1] 砂糖師三左衛門　　[2] 紀州

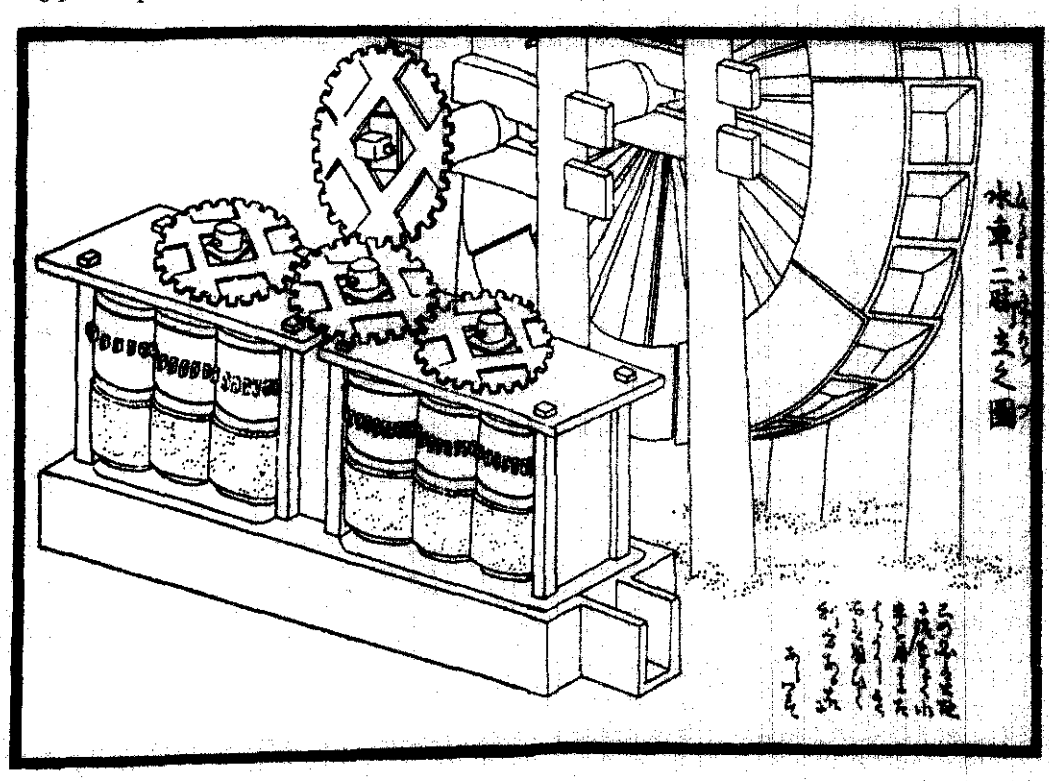


Fig. 95. A bank of twin, three-roller sugarcane mills with radially cogged gears powered simultaneously from a single vertical water-wheel in late +18th-century Japan. The rollers were constructed in stone with wooden cogs separately attached above. This illustration appeared in the *Satō Seisaku Ki* of +1797, pp. 8b–9a, but there was no explanation of it in the text. One wonders whether this mill was not similar to some of the Renaissance engineering illustrations that were designs rather than working plans of operational machinery (courtesy of the University of Tokyo Library).

complex water-driven configurations (see Figs. 94 and 95). The Japanese also popularised a device for feeding sugarcane into the rollers. They initially dubbed it *ōshi*[1] or duck's bill, the Japanese reading of the characters for *ya-tsui*[1], a device illustrated in the *Thien Kung Khai Wu*. Though the *Thien Kung Khai Wu* briefly referred to it as a device for feeding bagasse into rollers, no Chinese text ever provided a full description of it. The Japanese eccentric playwright and botanist, Hiraga Gennai[2], first explained it in his *Butsurui Hinshitsu*[3] (The Classification and Identification of Things) of +1763:[a]

As ... sugarcane stalks become soft and lose their firmness after an initial crushing, they are inserted [into the rolls through a device] called a duck's bill [on second and third crushings]. Bagasse is crushed by [being fed into the rollers] through the duck's bill and as it gets softer with each pressing, it should be twisted, as if twinning strands of rope, and then inserted into the rollers on the third pressing.

[a] *Butsurui Hinshitsu*, kan 6, p. 18a.

[1] 鴨嘴 [2] 平賀源内 [3] 物類品隲

The pressure feeder was previously thought to be a 20th-century invention,[a] but here we are able to confirm its use from the +17th century from the illustration in the *Thien Kung Khai Wu* (see Fig. 78a). The objective of this device was to feed the rollers with bagasse already under pressure from the duck's bill to achieve greater extraction and rate; the act of forcing the bagasse through the aperture in the feeder allows the rollers to travel faster and squeeze harder. The actual efficiency rate of the duck's bill is not known. However, Japanese sugarmakers appreciated it as a technique and Kume Eizaemon[1] of Sanuki Han[2], present-day Kagawa prefecture[3] on the island of Shikoku[4] redesigned it in 1819.[b] He dubbed it a *kitsuneguchi*[5] or fox's mouth, and it continued in use throughout the 19th century, and well into the 20th century in some areas (see Figs. 96a, 96b, 96c and 97). In 1983 I inspected one of these implements in the possession of Mr Okada Hidehiko[6], a manufacturer of *sanbon* white sugar[7] in Kamiitachō[8], Itano-gun[9], Tokushima prefecture[10] on Shikoku[11]. There, a metal funnel set in wood, called a *kitsune*[12] or fox, due to the resemblance to a fox's mouth, continued in use until the late 1940s. The large aperture of the funnel was 11 cm wide and 13 cm high, while the other opening gradually tapered down to a mere 1.8 cm. According to Okada this funnel worked in the following way. An operator would insert a wad of five or six stalks of bagasse through the wide opening of the funnel and position it between the rollers. The moving rollers firmly caught the bagasse, and their force pulled the funnel in towards the rollers thus ensuring a clean feed. It seems that the insertion of a wad of five or six stalks of bagasse though a small hole (the number of stalks inserted at once apparently depended on the amount of animal power) exerted greater pressure per unit of area thereby extracting more juice than possible by not using the funnel.[c]

The Japanese experience with the pressure feeder explains the instrument depicted in the *Thien Kung Khai Wu* illustration, but its subsequent application in China may have been confined to certain areas as the only other references that I have been able to find occurred in the journal of Henry Ellis of 1818 who described it as, 'a wedge-shaped aperture, with the smaller opening outwards', and in survey reports of Ssu-Chhuan during the 1930s, where sugar millers called it lion's mouth (*shih-kou*[13] or *shih-tzu-kou*[14]).[d] For a photograph of one in operation in late 19th-century Ssu-Chhuan see Fig. 97.

In Japan the space between the rollers was adjusted by driving in wedges.

[a] Meade and Chen (1), p. 70; also refer to review in Shann (1), p. 2347.
[b] Oka (2), p. 295.
[c] See Daniels, Christian (3).
[d] Ellis (1), p. 281; Kanda (1), p. 532; and Than (1), p. 148. Birch, J. G. (1), pp. 154–5 gives an excellent photograph of a sugarcane mill in central China at the end of the +19th century, that shows clearly a lion's mouth in operation (see Fig. 97). Stalks of a very thin clone are shown being fed into the instrument. Perhaps it was invented to cope with thin-stalked *S. sinense* clones.

[1] 久米榮左衛門 [2] 讃岐藩 [3] 香川縣 [4] 四國 [5] 狐口
[6] 岡田英彦 [7] 三盆白糖 [8] 上板町 [9] 板野郡 [10] 德島縣
[11] 四國 [12] 狐 [13] 獅口 [14] 獅子口



Fig. 96*a*. Figs. 96*a–c* all show the 'duck's bill' or 'fox's mouth'. Sugarcane was easily fed between the rollers on the first pass, but became difficult on second and subsequent passes as the bagasse became pliable. Chinese invented a device for pressure feeding the rollers with bagasse, that was first illustrated in the +17th century (see Fig. 78*a*). Bagasse from the first crushing of the stalks was fed through a wide mouth duck's bill (*ya tshui*[1]), or fox's mouth (*kitsuneguchi*[2]) as the Japanese dubbed it. The rollers pulled the bagasse through the tapered opening in the pressure feeder, which compressed it before making the pass. Various types of pressure feeders have been used in modern 20th-century sugarcane mills. Fig. 96*a* shows a pressure feeder (the fox's mouth, *kitsuneguchi*) positioned in front of rollers in an exhibit at the *sanbon* white sugar factory of Mr Okada Hidehiko of Kamiitachō, Itanogun, Tokushima prefecture, Japan; orig. photo Christian Daniels, 1983.



Fig. 96*b*. A front elevation of the pressure feeder shown in Fig. 96*a*; orig. photo Christian Daniels, 1983.

This facility, though only recorded for Ssu-Chhuan during the 1930s was probably present in China much earlier, but eluded documentation.[a] The Japanese modified the gearing so that it appeared on a separate wooden arrangement attached to the top of the stone rollers, thus enabling more rapid repairs and

[a] The only mention of such wedges in China that I know of occurred in Ssu-Chhuan during the 1930s where iron ones were called tortoises (*wu-khuei*[3]), see Kanda (*1*), pp. 531–2.

[1] 鴨嘴　　[2] 狐口　　[3] 烏龜

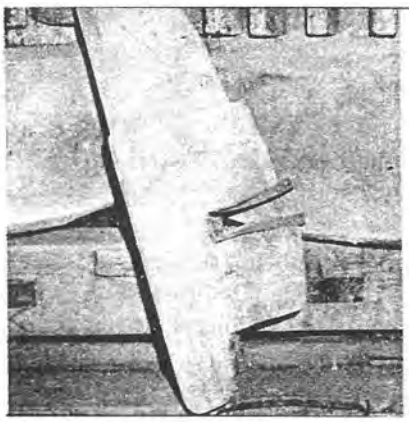


Fig. 96*c*. A side elevation of the pressure feeder shown in Fig. 96*a*; orig. photo Christian Daniels, 1983.



Fig. 97. A two-roller stone sugarcane mill in operation in central China in late 19th-century Ssu-Chhuan; Birch, J. G. (1), p. 153. The duck's bill is clearly visible between the rollers. It was known as a lion's mouth (*shih khou*[1] or *shih tzu khou*[2]) in Ssu-Chhuan during the 20th century, see Kanda (*1*), p. 532 and Than (*1*), p. 148.

servicing.[a] This modification has also been observed on Chinese mills in Java but not in China itself where it may have been employed though unrecorded.[b]

[a] Ota (1), p. 465.

[b] Dodds (2), fig. on p. 2.

[1] 獅口

[2] 獅子口

Later we shall meet the same Japanese capacity to accept and perfect new technology under clarification, where they adopted settling tub techniques imported from China.

In the West engineers improved the efficiency of vertical three-roller mills with such concepts as the *doubleuse*, promoted by Dutrône la Couture in +1790, which guided bagasse out of the first set of rollers to return through the second set reducing the need for one attendant;[a] this device of course saved labour. Towards the end of the +18th century a significant change from vertical to horizontal roller milling occurred.[b] The reasons for the triumph of the horizontal mill appear to have been two-fold. First, with the advent of steam power, it became possible to load greater quantities of sugarcane into the mill at the one time. With a horizontal mill the full width of the roller can be utilised from a bench feed or gravity chute, an impossible strategy for a vertical mill. Second, at this time engineers rediscovered bevel gears, which initially appeared as early as Leonardo, and applied them to animal-driven, horizontal sugarcane mills.[c] This meant that the horizontal mill could be turned by animals in the same manner as vertical mills which caused an immediate decline in the use of the latter. This supports my previous contention that vertical mills were promoted over horizontal mills because of the simple animal drive. It should be added in this context that bevel gears were a child of the times, and impossible in wood with renaissance engineering.[d]

(4) Refined Sugar Products: Clarification

(i) *Introduction*

Sugar makers in ancient, medieval and 20th-century China and India, deliberately did not clarify the crude sugars, respectively known as *hei-thang*[1] and *gur*, because consumers favoured the flavour of the impurities they contained. In fact, Sir George Watt commented on how established preferences stood in the way of erecting modern European sugar mills in 19th-century India as no great mass consumer market existed for factory-made sugar with most of the impurities removed: 'It seems probable that the greatest difficulty of all lies in the social habits of the people of India. They prefer the dirty sugar which Messrs J. Travers and sons compare to manure.'[e] Yet the truth of the matter is that since all sugars were produced by the application of heat to syrups, even these 'manures' did undergo minimum clarification. Heat releases air bubbles and

[a] Through Barrett (1), p. 53.
[b] Fraginals (1), p. 36.
[c] *Codex Atlanticus* fol. 372r; see illustration of such a 19th-century sugar mill in Fraginals (1), p. 104.
[d] Metal gears only became common c. +1770, see Davison (5), p. 132.
[e] Watt (1), vol. 6, pt 2, p. 113.

[1] 黑糖

coagulates some impurities as well as evaporating moisture and, if skimmed, syrups turn into a partly clarified product which becomes more stable with time. In addition, there have been at all times, partial clarifications specifically designed to retain the desirable 'manure' taste, while enhancing the keeping quality. In fact, the major objective of all refining is the manufacture of a stable product that will not deliquesce and deteriorate. If taken to the ultimate in white sugar manufacture, clarification 'is the removal of as large a quantity as possible of all impurities, especially of those which impede the obtaining, by evaporation and crystallisation, of a large quantity of pure cane sugar'.[a]

This statement made in the 20th century was just as relevant when white sugars were first produced, probably in India about the time of Christ. In my general outline of manufacture earlier (pp. 276–7), I characterised impurities by kind as reducing sugars, other organic matter and ash. From the point of view of the separation of impurities, however, juice is best regarded as a dispersoid of various classes:[b]

1 *Coarse* soil, wax, bagasse
2 *Colloidal* fats, proteins, gums, some colouring matter
3 *Molecular* colouring matter, tannins, enzymes
4 *Ionic* ash.

This further physical breakdown is helpful as these dispersoids react differentially to treatment. An additional necessary factor in appreciating the problems involved is that the juice expressed from sugarcane remains acid, 5.2 to 5.5 pH, potentially leading to the destruction of sucrose by inversion into glucose and fructose.[c] Here we come to another distinction between 'manure' makers and modern refiners; the former positively encouraged the inversion of sucrose to glucose and fructose in order to increase flavour. I shall discuss methods of clarification beginning with heat.

(ii) *Clarification by heating*

Heating and skimming were the oldest and most effective methods of reducing impurities. The principle is simple; impurities become attached to air bubbles released by the heating, and so rise to the surface as a scum. That long-time +18th-century resident of the West Indies, James Grainger, in his poem, *The Sugar-Cane*, of +1764 emphasised the importance of skimming:[d]

> Thy foaming coppers well with fuel feed;
> For a clear, strong, continued fire improves
> Thy muscovado's colour, and its grain.
> Yet vehement heat, protracted will consume

[a] Zerban (1), p. 204.
[b] Payne (1), p. 502.
[c] Baikow (1), p. 92 and Jenkins (1), p. 174.
[d] Chalmers, Alexander (1), vol. 14, p. 500.

Thy vessels, whether from the martial mine,
Or from thine ore, bright Venus, they are drawn;
Or hammer, or hot fusion, give them form.
If prudence guides thee then, thy stores shall hold.
Of well-siz'd vessels a complete supply:
For every hour, thy boilers cease to skim,
(Now Cancer reddens with the solar ray)
Defeats thy honest purposes of gain.

Noel Deerr conducted experiments which indicated that heat alone accounted for 75 per cent of the effect obtained by applying more comprehensive clarification with heat and lime.[a] Most 'manure' sugar makers shunned skimming. In India sugar makers applied lime sparingly, pH being kept under 7.0, as Indians disliked the taste of limed sugar.[b] The coarse dispersoids are not affected by heat, and are merely physically removed by skimming, while the colloids are coagulated and rise with a small proportion of the molecular dispersoids adsorbed. Another most important factor is the destruction of enzymes by heat. The invertases, which occurr naturally in the whole sugarcane plant to regulate sucrose accumulation, are potentially dangerous for loss of sucrose by inversion, but fortunately they are heat labile and are destroyed as soon as boiling commences.[c] The other more useful natural enzyme, α-amylase, added to delay tanks in some modern factories to reduce starch in juice,[d] probably has time to act with the normal delay in processing in peasant situations.

No Chinese text discussed heat or recorded skimming in more complex clarification processes. Yet during the +13th century Marco Polo observed, 'but making it boil they [the Chinese] only skimmed it', and as 19th-century European authors also observed skimming in China, it is obvious that Chinese authors thought it a self-evident procedure.[e] Heating and skimming must have been raised to a high art because as demonstrated in the *Thang Shuang Phu* of c. +1154 Ssu-Chhuanese sugar boilers made excellent sugar candy without any clarifying agents during the +12th century. Sun & Sun claimed that the *Thang Shuang Phu* mentioned lime as a clarifier, but we have not been able to find references to lime or any other clarifying agent in this source.[f]

The power of heating alone cannot be underestimated. Jorges Chandra Ray, an early 20th-century outstanding Indian historian of science, to whom we shall return, conducted a multi-disciplinary investigation in 1918 on the history of sugar making in India. He discussed heat clarification in the following terms:[g]

[a] Deerr (3), p. 559.
[b] Yamane (1), p. 501.
[c] Alexander, A. G. (1), p. 597.
[d] Meade and Chen (1), p. 137.
[e] Moule & Pelliot (1), p. 347; Lock, Wigner and Harland ((1), p. 622) and Couling ((1), p. 530) have summarised 19th-century sources on skimming in their account of clarification in China.
[f] Sun & Sun (1), p. 132, fn.8. Mazumdar (1), p. 172 also concurs with me on this point.
[g] Ray J. C. (1), p. 443.

We do not know how the ancients clarified their juice or refined their sugar. Very likely the method was much the same as obtains now in Bengal and elsewhere. As far as my information goes, boiling juice is clarified by simply skimming off the scum which rises to the surface. The sugar-boilers of Bengal, who are professional men, do sometimes add milk, but only on special occasions. They attach more importance to the race of the sugarcane and to the factors of timely cutting and pressing and of boiling the juice than to the addition of extraneous defecators. Yet the best *gur* is as good as muscovado or even candy, though not white.

If sugar boilers applied an additive at the time of the *Thang Shuang Phu*, it was most likely milk.

(iii) *Clarification with milk*

Milk must be regarded as the earliest, and certainly one of the most effective clarifying agents. It is an emulsion of fat in water stabilised by phospholipoids, which are absorbed on to fat globules. It is slightly acid to almost neutral with a pH range of 6.3 to 6.9.[a] On addition to cane juice and with heating, milk forms a dense floc in which suspended matter is trapped and on which the molecular dispersoids, in particular the complex colouring matter, are adsorbed. This results in a very powerful clarifier when combined with the coagulation of the colloids by heat.

Milk clarification probably commenced in India after +400, as the sugar *pushpa-sitā* specifically related to milk clarification does not appear in the early authoritative texts the *Caraka Saṃhitā* (+1st to +2nd century), *Ṣuśruta Saṃhitā* (+4th century) and the Bower manuscript of c. +375.[b] Deerr suggested that the Persians possibly possessed an ancient tradition of milk clarification on the basis that *tabarzad* is one of the sugars mentioned by the Arab geographers. He cited a +1756 Persian dictionary, the *Mustalahat-i-Behar-i-Agam*, which recorded the production of *tabarzad* as syrup 'boiled with the addition of one-tenth part of milk'.[c] Milk-clarified sugars must have evolved by the early +7th century when they appeared in Chinese texts as *shih-mi*[1] and were ascribed to India and Persia.[d] Von Lippmann in fact has credited the Nestorians in Iran with possessing skills in sugar manufacture and amongst other things claimed that they invented techniques for draining sugar.[e] Laufer claimed that von Lippmann's hypothesis is nothing more than ingenious speculation, but failed to provide any solid evi-

[a] Osepchuk (1), p. 523.

[b] Ray J. C. (1), pp. 444–5 and Deerr (1), p. 47. Datings from Winter (1), pp. 149–50.

[c] Deerr (1), p. 450.

[d] The term *shih-mi*, which on the basis of later Chinese pharmacopoeias such as the *Shih Liao Pên Tshao* (*PTKM* p. 1891) of +670 referred to milk-clarified sugar, appeared in the *Sui Shu*, p. 1857 and the *Wei Shu*, p. 2278 for India (*Nan Thiên Chu*[2]). One also wonders whether the *shih-mi* recorded for India (*Thien Chu Kuo*[3]) in the *Hou Han Shu*, p. 2921, also referred to milk-clarified sugar.

[e] von Lippman (4), pp. 160–1.

[1] 石蜜 [2] 南天竺 [3] 天竺國

dence to substantiate his refutation.[a] The same can be said of Deerr's hypothesis.

The *Shih Liao Pên Tshao*[1] of +670 was the first Chinese text to mention milk clarification:[b]

Shih-mi ... That from Shu[2] [Ssu-Chhuan] and Persia are good. Eastern Wu[3] also has it, but it is not as good as that of the former two places. This is all [made by] boiling the juice of sugarcanes with cow's milk and it will turn fine and white.

The addition of milk to sugar products actually appeared earlier in the *Hsin Hsiu Pên Tshao*[4] of +659:[c]

Boil [*sha-thang*[5]], water, cow's milk, rice flour together to make lumps of *shih-mi*, and hard and heavy cakes (*ping*[6]). The ones that come from the Western barbarians are excellent. Chiang-Tso[7] [Chiang-Su] also has it and it is generally superior to that from Shu [Ssu-Chhuan].

Schafer argued that small honey cakes, also called *shih-mi*, a delicacy of the early Thang, were replaced by those manufactured from sugar *sha thang*.[d] The above text indicated that sugar cakes and 'biscuits' were probably in vogue during the Thang. It is possible that these sources, which are highly specialist pharmacopoeias, may have diverted attention away from the practice of milk clarification in making ordinary sugar as well as 'biscuits'.

These pharmacopoeias make the point, also recorded later in Egyptian, Chinese and Indian texts, that sugar boilers used milk in clarifying sugar that had been boiled once, rather than cane juice.[e] The *Thu Ching Pên Tshao*[8] of +1061 recorded; 'Reboil *sha thang*, mix it with cow's milk to make *shih-mi*. This is milk sugar (*ju-thang*[9]).'[f] In addition the *Pên Tshao Yen I* of the +12th century remarked that contemporaries call *shih-mi* milk sugar (*ju-thang*).[g] Sugar makers probably practised milk clarification of re-boiled sugar rather than juice to reduce the expenses of milk in larger-scale operations. After these texts, milk as a clarifying agent disappeared from Chinese literature, though it continued until the early 20th century in India, for which we have detailed descriptions.[h] There, sugar-boilers continually added small quantities of milk to the boiling pan and removed the resulting skum until it stopped rising. Practitioners probably followed this procedure in Thang China as it economised on the amount of milk thereby ensuring against over application.

[a] Laufer (1), pp. 376–7.
[b] Quoted in *PTKM* p. 1891.
[c] Quoted in *PTKM* p. 1891.
[d] Schafer (13), p. 153.
[e] This also applies to eggs.
[f] Quoted in *Chêng Lei Pei-Yung Pên Tshao*, ch. 23, p. 28a.
[g] Quoted in *PTKM* p. 1891. The *Chiu Wu Tai Shih*, p. 1463 also listed milk sugar (*ju-thang*).
[h] Watt (1), vol. 6, pt 2, p. 268; Ray, J. C. (1), p. 443.

[1] 食療本草 [2] 蜀 [3] 東吳 [4] 新修本草 [5] 沙糖
[6] 餅 [7] 江左 [8] 圖經本草 [9] 乳糖

(iv) *Clarification with plant additives and ashes*

19th-century Indian sugar boilers utilised various plant additives and ashes for clarification including the bark of *polo* (*Kydia calycine*) and *dhaman* (*Grewia appositifolia*).[a] Ashes included the plantain tree (*Musa*),[b] *bhendi* (*Hibiscus esculentus*),[c] ashes of myrobalam, and milkbush or *aghāda* (*Archyranthus aspera*).[d] I have not found extensive evidence of the use of plant extracts for clarification in China, though there are references to *musa* ashes as clarifying agents in Vietnam during the +18th century.[e]

The applications of ashes in China possibly dated from the Yüan dynasty as Marco Polo discussed them:[f]

> But you may know that before the great Kaan had conquered them the people in those parts did not know how to do up or make sugar so finely and as well as it is made in the parts of Babilonie; for they used not to make it set and cling together in loaves, but making it boil they only skimmed it and then when it was cold it stayed like paste & black. But when it became subject to the great Kaan, people from the regions of Babilione were found at the court, who going to those parts taught them to refine it with the ashes of certain trees.

Most scholars, including Deerr, regarded this as a factual report.[g] The Yüan dynasty in fact boasted a government-administered Sugar Bureau (*Sha Thang Chü*[1]), the scope of which may have included the introduction of new technology.[h] Mazumdar was sceptical of Marco Polo's observations because she failed to find any mention of ashes in the description of sugar making in Babilione (Egypt) by al-Nuwairī (+1279 to +1334).[i] Al-Nuwairī was not ignorant of clarification procedures as he described egg clarification of once-boiled sugar.[j] In addition Ibn Batuta, who visited the same regions of China within twenty-five years of Marco Polo, wrote, 'you find in China a great deal of sugar as good as that of Egypt, better in fact ...' indicating equal or better sugar quality in China.[k] Mazumdar also claimed a lack of documentation of ashes in China. However, the +1503 gazetteer for Hsing-Hua prefecture, cited earlier, mentioned the addition of ashes to pulverised cane before washing and diffusion.[l] A Yüan agricultural treatise, the *Nung Sang Chi Yao* of +1273, did not mention

[a] Watt (1), vol. 6, pt 2, p. 299.
[b] *Ibid.*, p. 270.
[c] *Ibid.*, p. 300.
[d] *Ibid.*, p. 304.
[e] Poivre (1), pp. 108–9. The sugar boilers may have been Chinese.
[f] Moule and Pelliot (1), p. 347.
[g] Deerr (1), p. 578.
[h] *Yüan Shih* p. 2204.
[i] Mazumdar (1), p. 139.
[j] Translation in Deerr (1), pp. 90–1.
[k] Yule (2), vol. 4, p. 108.
[l] +1503 *Hsing Hua FC*, ch. 12, pp. 11a–11b.

[1] 沙糖局

ashes as a clarifier. This question must be left open as the first reference we have been able to find to ashes outside China occurred in the temper prescribed by Richard Ligon in his *A True and Exact History of the Island of Barbados* of +1657.[a]

(v) *Clarification with lime and eggs*

In both East and West, ash clarification preceded the application of lime, which first appeared in the *Thien Kung Khai Wu* of +1637.[b] In the West Angelus Sala in his *Saccharologia* of +1637 recommended lime as a clarifying agent for refining in Europe, but eggs and blood continued to hold sway.[c] This must have had some effect as Henri Duhamel du Monceau in his *L'Art de Raffiner le Sucre* of +1764, which described methods employed in +18th-century France, mentioned lime water as the basic clarifier with eggs and blood as adjuncts, although some factories applied lime water alone.[d] Ashes also continued to find favour for Ligon reported them for Barbados in +1657, and Antonil for Brazil in c. +1700.[e] Lime additives first appeared in a complex lye concocted by Father Jean Baptiste Labat who wrote about the Martinique of +1690.[f] Father Labat included lime in a clarifying composite of ashes and herbs, which Fraginals has dubbed a rural alchemistic technique.[g] The application of a pure lime additive for sugarcane processing seems to date from John Proculus Baker's *An Essay on the Art of Making Muscavado Sugar* of +1775.[h] From this time we can observe a universal acceptance of lime for clarification in plantation and commodity processing. Lime acts primarily by forming a dense floc of complex calcium phosphates on to which molecular dispersoids, colourants in particular, are adsorbed and in which some suspended matter is trapped.[i] The floc may sink to form a sludge, or if aerated and especially if in a heavy syrup, may rise to form a scum. The addition of the correct amount of lime plays a critical role. As regards this matter the initial report in the *Thien Kung Khai Wu* was terse but instructive: 'add five *ho*[1] [518 ml] of lime (*shih-hui*[2]) to every *tan*[3] [103 litres] of cane juice'.[j] The rate given was precise, indicating some years of experience and experimentation. Artisans may even have transferred expertise from some other technology, such as paper making, to sugar manufacture.[k]

[a] Ligon (1), p. 90.
[b] *TKKW*, p. 167. Hereafter lime seems to have been consistently used for a gazetteer for southern Taiwan, the +1717 *Chu-Lo HC*, p. 195 recorded the employment of oyster shells in sugar boiling.
[c] Deerr (1), p. 578. Eggs and ox-blood played essentially the same role as lime they all caused the precipitation of colloids in the syrup.
[d] Duhamel du Monceau (1), pp. 17–21.
[e] Ligon (1), p. 90 and Antonil (1), pp. 204–5.
[f] Labat (1), p. 278.
[g] Fraginals (1), p. 39.
[h] Edwards (1), vol. 2 pp. 236–7.
[i] Honig (1); Payne (1); and Davies (1).
[j] *TKKW* p. 167.
[k] Vol. 5, pt 1, p. 7.

[1] 合 [2] 石灰 [3] 石

The precise application, five *ho* of lime per *tan*, matched the recommendation of Bryan Edwards in his *The History, Civil and Commercial, of the British Colonies in the West Indies* of +1793.[a] This close correspondence is most interesting as Davies, a 20th-century researcher, suggested that pioneers in the use of lime could have been guided to the right concentration by colour changes in the cane juice.[b] Edwards urged his contemporaries to adopt his concentration which amounted to about half of the usual rate. Modern research has shown that there are pH sensitive colourants which imparted increased coloration at higher pHs.[c] Sung Ying-Hsing and Bryan Edwards' conservative application of lime patently derived from accurate observation, probably including colour changes which indicate overdosing. Modern researchers have also shown that reducing sugars decompose at higher pHs, and some components of the floc redissolve, so overliming is clearly undesirable.[d] The optimum pH is just over 7.0 (neutral), but varies with the juice treated, which can be modified by delays in crushing sugarcane, frost and other acts of God.

China witnessed a significant development in clarification technology during the +17th century after the publication of the *Thien Kung Khai Wu*. Artisans noted that if they skimmed limed juice to remove obvious scum, and then allowed it to stand in a vessel without skimming, the floc matured and the heavier matter sank. On the other hand, lighter material rose to the surface as a blanket, leaving clear, brilliant juice in the space between them. The clear juice was then drawn off through holes in the side of the vessels which were normally plugged with wooden stoppers. The earliest documentation for this device appeared in the +1726 submission on Chinese sugar-making methods to the Japanese authorities by the Chinese merchants at Nagasaki. It explained the precipitation bucket for making white sugar:[e]

Place sugarcane juice in a boiling pan and apply approximately three to four *liang*[1] (112–149 gm) of oyster shell lime (*hao ku hui*[2]) to every two hundred *chin*[3] (64 kilos) of sugarcane juice. Boil (*chu kun*[4]) it together and use a copper ladle (*thung chhing chhih*[5]) to remove the scum (*ni cha*[6]). After boiling it up a few times put the juice in a wooden bucket (*mu thung*[7]) and allow the sediment (*cha ni*[8]) to settle at the bottom of the bucket. Bore two holes in the lower half of the bucket and plug them up with wooden stoppers. Pull out the wooden stoppers and the clear juice drains down into the boiling pan. Take the clear juice in the upper levels [of the bucket] and boil it again until it becomes like the broth of boiled rice (*êrh kan*[9]). Then ladle it into the wooden bucket for a second time and make the sediment (*cha ni*[8]) settle at the bottom of the bucket. Remove the

[a] Edwards ((1), vol. 2, p. 232) suggested half a pint of Bristol lime to every hundred gallons of cane juice. See Porter (1), pp. 66–7 for a more complete discussion of the problems of liming in the West Indies.

[b] Davies (1), p. 53.

[c] Gillett (1), p. 248.

[d] Honig (2), p. 498.

[e] For the transcripts of the information the Chinese merchants provided the Japanese see Ôba (1), pp. 321–5. Daniels, Christian (3), pp. 8–9 and (3), p. 44 mistakenly claimed that this tub precipitation was a Japanese innovation. It is now clear that the Japanese acquired the technology from China.

[1] 兩 [2] 蠣殼灰 [3] 觔 [4] 煮滾 [5] 銅清匙
[6] 泥渣 [7] 木桶 [8] 渣泥 [9] 二甘

wooden stoppers in the two holes bored in the lower half of the bucket, draw the clear juice off into a boiling pan, and boil it again. When the sugar in the pan is about to boil over (*kun fu man chhu*[1]) add a few drops of sesame oil (*ma yu*[2]) and it will cease.

This method included two settlings, but was sometimes reduced to one, as noted by Henry Botham for Sumatra. Surveys of precipitation bucket practices in Taiwan during the late 19th century documented the two settlings. In the first settling the juice was limed in the bucket, called a *phi tzu thung*[3] before commencing boiling, and the second took place after the juice had been heated in the first boiling pan and the precipitated juice separated from the impurities.[a]

Tub precipitation produced a clear juice which yielded purer sugar with less impurities. The maturation of the floc coupled with adequate settling time allowed complete separation of the floc and the adsorption of impurities onto the floc. It is precisely for this reason that sugar boilers adopted the above method, illustrated for making white sugar in the *Satō Seisaku Kī* of +1797 (see Fig. 98).[b] At about the same time Henry Botham, experienced in Chinese methods in Sumatra, testified to an English commission investigating slavery:[c]

> The cane-juice is tempered and boiled to a syrup, it is then thrown into vats which hold one boiling, then sprinkled with water to subside its foul parts: after standing for six hours, it is let off by three pegs of different heights into copper pots with one fire.

This method applied clarification technology to the syrup rather than the juice, which explained why sugar boilers allowed a longer period of time for settling. Tub precipitation technology provides another example of how with sugar technology we can glean more details about Chinese practice from reports abroad than from indigenous sources.[d] In +1775, John Proculus Baker documented the settling phenomenon in Jamaica, and Samuel Sainthill added the concept of siphoning out the clear juice, creating a process essentially similar to the Chinese method. Sainthill received a patent from the Jamaica Assembly in +1778 for his efforts.[e]

Sugars are clarified by dissolving in water (melting in the jargon of sugar technologists) to about 70 per cent solids. After the addition of lime, the scum rises because of the high specific gravity of the syrup. This differs from juice in which the heavy particles settle and the light ones rise leaving clear juice in the middle. Henri Duhamel du Monceau was the first to elaborate on clarification in his *L'Art de Raffiner le Sucre* of +1764.[f] He pointed out that the only treatment appropriate for heavy syrups of high density was what he named *élévation* of the

[a] Hara (*1*), pp. 31–2.

[b] For an account of tub precipitation in Japan today see Daniels (2), p. 10, photos 31-33.

[c] East India Company (1), p. 84.

[d] No pre-19th-century sources mentioned tub precipitation in China, though we know from the above account that the Chinese did practise it. Hara ((*1*), pp. 31–3) observed it in Taiwan in the period 1896 to 1897; and Kanda (*1*), pp. 535–6 described it for Ssu-Chhuan during the 1930s.

[e] Edwards (1), vol. 2, pp. 236–7. Edwards noted disapprovingly that Sainthill procured a patent from Baker's invention.

[f] Duhamel du Monceau (1), pp. 21–5.

[1] 浪浮滿出 [2] 麻油 [3] 皮仔桶

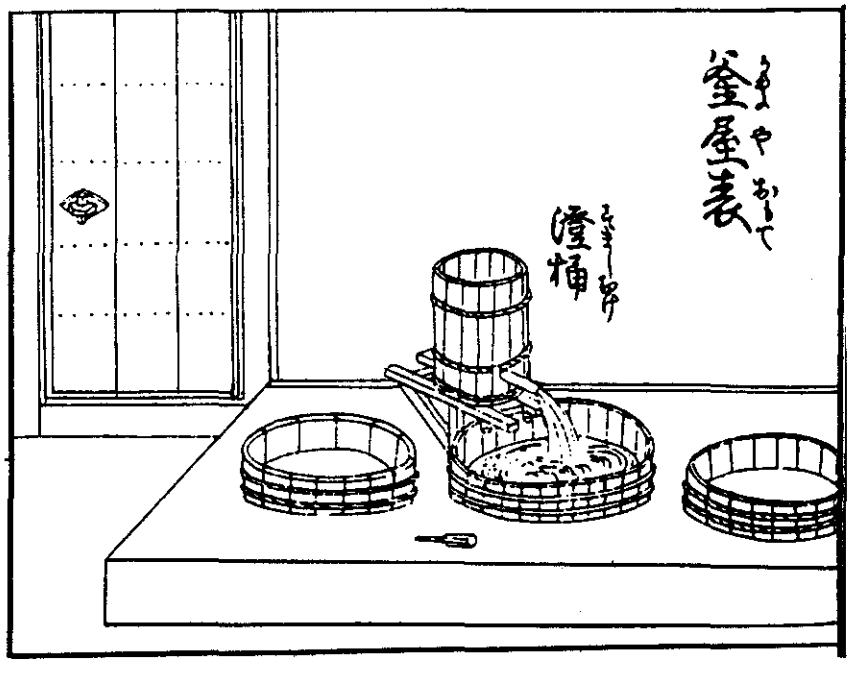


Fig. 98. A clarification settling tub. Lime was added to the juice, heated, skimmed and transferred to the tub. After the precipitate settled, clear juice was drawn off from the hole in the side of the drum until the scum on the surface was reached. The scum and dregs were then transferred for reprocessing; *Satō Seisaku Ki*, p. 11a (courtesy of the University of Tokyo Library).

scum. To him *précipitation* and *filtration* seemed inappropriate techniques due to the high density of the syrup. His method was to dissolve raw sugar in lime water and then add an additional clarifying agent, the white of eggs, at the rate of 70–90 eggs to 4–4.5 tons of raw sugar, or more preferably with two gallons of blood. Eggs and blood continued as preferred clarificants until the advent of the modern carbonation processes in the mid-19th century.[a] West Indian sugar boilers also practised the application of clarifying agents to heavy syrups in raw sugar manufacture, and dubbed it the French method of clarification.[b]

[a] Clow & Clow (1), pp. 521–2. Carbonation consists of adding excess lime to the dissolved sugar and precipitating the excess as calcium carbonate by bubbling carbon dioxide flue gas through the liquor, see Deerr (1), p. 464 for history.

[b] Deerr (1), p. 465. Deerr gave a useful summary of Duhamel du Monceau. The 'French' method was also practised in some areas of China. The *THSCL* of +1736 pp. 56–7 suggested the following: 'For usage of lime (*hui*[1]); when the syrup boils up vigorously add oyster shell lime (*li fang hui*[2]). For usage of oil (*yu*[3]); Add oil from the castor oil plant (*pi ma*[4] [*Ricinus communis* L. R331]) when the sugar is about to crystallise.' The +1717 *Chu-Lo HC*, p. 194 also recorded the application of castor oil at a similar point in the boiling process in southern Taiwan. Dosages of oil and fat at the crystallisation point were common in Chinese areas of influence. They have been noted in places as far apart as Java and Japan, see Rumpf (1), vol. 5, pp. 186–91 for mention of the addition of chicken fat when making sugar candy in Amboina, and Ōba (*1*), pp. 321–5 for introduction in Japan. It is known that oil and fats were applied to reduce frothing, but mill operators in Japan claimed that camellia oil imparts a fragrance to the sugar, see Daniels, Christian (2), p. 11.

[1] 灰 [2] 礪房灰 [3] 油 [4] 蓖麻

Egg albumen as an additive in making high-quality sugars dated back at least to al Nuwairī. It was first mentioned for China in the +1503 gazetteer for Hsing-Hua prefecture, in Fukien:[a]

White sugar (*pai-thang*[1]); made in the first lunar month of each year by refining (*lien*[2]) *sha-thang*[3]. Select good and dry *sha-thang*, put it into a large cauldron (*ta fu*[4]) and boil (*phêng lien*[5]). The albumen and yolk of a duck's egg[b] are mixed into [the boiling juice] to make the impurities float to the surface. Use a perforated iron skimmer (*thieh ku li*[6]) to scoop [the impurities from the surface] and make it clean. Watch the fire and wait until [the syrup has been boiled] sufficiently [before ladling it into the cones].

Egg albumen clarification was later applied to provide a superior feedstock for a range of speciality sugars including pure white (*chieh pai-thang*[7]), sugar candy (*thang-shuang*[8]), and honey pieces (*mi phien*[9]). We find in the *Min Shu*[10] of +1631.[c]

Take official sugar (*kuan thang*[11]) [a medium grade clayed sugar] and boil (*phêng lien*[12]) it again. Break a hen's egg and stir it [into the syrup] to get the impurities to float to the surface. Once again put [the massecuite crystals in sugar] into a porcelain drainer [*tshu lou*[13]) and cover it with clay as before. The colour will turn even whiter and it is called pure white sugar (*chieh pai-thang*[7]). The molasses that comes off is called pure water (*chieh shui*[14]). Furthermore, take [the pure white sugar (*chieh pai-thang*[7])] and boil it to make sugar candy (*thang-shuang*[8]) and honey pieces (*mi-phien*[9]).

We see here the action of egg clarification in combination with crystallisation and drainage in the manufacture of the highest-grade sugars. These were obviously small-scale operations akin to the +18th-century French confectionery laboratories portrayed in the great *Encyclopédie* of Diderot.[d]

(vi) *Conclusions on clarification*

Sugar boiling from its inception included minimal clarification because heat, the major clarifying agent, served to concentrate the cane syrup and release air bubbles which rose to the surface trapping various suspended particles on the way. Removal of scum in boiling alone, led to the production of ordinary grades of sugar which peasants still consume today, such as *hei thang* and *gur*. The *Thang Shuang Phu* of c. +1154 showed that careful heating and skimming alone, with appropriate crystallisation and drainage, can lead to the production of the highest quality sugar. During the Thang dynasty artisans made ex-

[a] +1503 *Hsing Hua FC*, ch. 12, pp. 11a–11b. Ducks' eggs also appeared in the +1530 *Hui-An HC*, ch. 5, pp. 20a–20b.

[b] The *MS*, ch. 150, p. 33b recorded fowls' eggs, and Rumphius (1), vol. 5, pp. 186–91 reported the whites of eggs, and the *KTHY* p. 389 mentioned the albumen of ducks' eggs.

[c] *MS*, ch. 150, p. 33b. The *TKKW*, p. 170 also recorded egg albumen (*tan chhing*) for clarification in making sugar candy (*ping-thang*).

[d] Gillispie (2), vol. 2, pls. 480–483.

[1] 白糖 [2] 煉 [3] 沙糖 [4] 大釜 [5] 烹煉
[6] 鐵笊籬 [7] 潔白糖 [8] 糖霜 [9] 蜜片 [10] 閩書
[11] 官糖 [12] 烹鍊 [13] 瓷漏 [14] 潔水

ceptionally high quality sugar with milk clarification, but this technique lapsed during the Sung, possibly due to the traditional Han Chinese abhorrence of dairy products. Ashes came into use as an additive from some point in time, and may be attributed to a transfer by the agency of people coming from 'Babilione' during the Yüan period.

World sugar production changed with the discovery of lime for clarification as it paved the way for the manufacture of purer sugar (more impurities separated). The Chinese never employed ox-blood, so popular in European refineries, but they can claim a clear priority for the widespread application of lime in sugarcane processing as the *Thien Kung Khai Wu* of +1637 and later texts described its application. It was not employed in the Caribbean until +1750. Perhaps of more consequence, however, was the Chinese discovery during the +17th century that clarification could be vastly improved by separating the clarification from the boiling step. If lime is added to juice, heated and left to stand, a dense floc results. Impurities are adsorbed on and trapped in the floc, which separates leaving clear, brilliant juice that can be readily siphoned off from the vessel by tap; unaerated floc sinks and, while attached to bubbles, rises. This finding is the basis of 20th-century clarification, and all subsequent improvements.

(5) Refined Sugar Products: Boiling Techniques

The largest 'impurity' in sugarcane juice is water; it varies from about 85 per cent to 90 per cent of the sugarcane. Energy has to be supplied to reduce the water in expressed juice to about 10 per cent in cane syrup to achieve crystallisation. Clones of the species *S. sinense*, *S. barberi* and modern *Saccharum* spp. hybrids, of 12 per cent to 16 per cent fibre, contain enough fuel in the bagasse to boil off this water.[a] However, with clones of *S. officinarum* that have below 10 per cent fibre, extraneous fuel has to be employed even in efficient factories. Such is the capricious nature of man, that forests were chopped down in most countries to feed the boilers, until the wood ran out. As has been said previously, sugar manufacture and ore smelting have been held responsible for the deforestation of the Mediterranean region. This partly arose because until the advent of the roller mill in the +16th century, which crushed out the juice and left the stalk in a condition suitable for feeding into furnaces, bagasse was not delivered in a state fit for stoking rudimentary furnaces. The early equipment, edge-runners and trip-hammers, reduced the cane to pulp which proved difficult to feed into furnaces. In Brazil the use of wood lingered on two hundred years after the invention of the roller mill, even though fuel expenses could amount to 30 per cent of the cost of running a plantation.[b] On the positive side, in some areas

[a] Watt (1), vol. 6, pt 2, pp. 278, 285.

[b] Galloway (3), p. 342. Schwartz ((1), p. 118) cited José da Silva Lisboa who reported that 'about eight cartloads of well-sorted firewood was needed to process eighteen to twenty cartloads of cane'.

of India, peasants considered the fibre from roller mills too valuable for burning, because of its excellent qualities for making ropes and mats.[a] As regards China, we have noted above that the availability of wood as fuel probably aided the rapid development of lands for sugarcane south of the ranges. When Chinese sugar millers found immediate wood sources depleted, their roller mills allowed them quickly to change over to bagasse.

Initially the Chinese utilised the sun to remove water; juice was run onto mats and solar evaporation reduced it to a thick tacky mass, likened to malt sugar *i*[1], or the hard amorphous mass called *shih-mi*[2], and compared to hard malt sugar *hsing*[3]. Boiling undoubtedly commenced with pottery vessels, as the art of pottery was prehistoric and prominent in archaeological discoveries in south China.[b] We lack specific information on the progress of boiling technology yet, as operations remained small, it is reasonable to suppose that developments followed general trends in culinary apparatus. Chang has represented a wide shallow utensil, the *ho*, the fore-runner of the modern *wok*, and similar to 19th-century boiling pans, which were available from the Shang and Chou dynasties.[c] From the Thang, copper utensils replaced ceramic vessels in the culinary arts, and sugar manufacture probably followed this trend, but it is the *Nung Sang Chi Yao* of +1273 before any documentary evidence appeared.[d] In this instruction manual, the subject is put as an injunction, 'use a copper boiling pan (*thung kuo*[4])', indicating that a ceramic option might be considered feasible, but was considered inferior.[e] Later large iron pans became common, although again dating is conjectural. Iron pans probably came into general service from the early[f] +16th century when commodity production arose, but as iron *woks* were common in Chinese kitchens during the Sung, they could have appeared earlier. The design tended towards wider and shallower pans to provide greater surface area for evaporation. The ultimate development in Afghanistan and Pakistan is shown in Fig. 99, but it is not possible to document a trend in the Chinese sphere of influence.

The *Nung Sang Chi Yao* also elaborated on boiling pans:[f]

> Use a copper pan. Boil the juice with a slow or quick fire, taking into consideration the amount [of juice]. Place this pot and arrange the fire outside the partition wall. Do not let any smoke get into the pot; have a person solely to watch over this.

Mazumdar has pointed out that this rather obscure text referred to the traditional Chinese oven as described and illustrated by Hommel, where a brick

[a] Watt (1), vol. 6, pt 2, p. 299. In some areas of India about 30% of the bagasse was used for making ropes, see *ibid.*, p. 294.
[b] Meacham (3), pp. 157, 161.
[c] Chang (7), fig. 2.
[d] Schafer (25), p. 124.
[e] *NSCY*, ch. 6, p. 14a.
[f] *Ibid.*

[1] 飴 [2] 石蜜 [3] 餳 [4] 銅鍋



Fig. 99. A large boiling pan used in 20th-century Peshawar, Pakistan. These large boiling pans are the ultimate in open-pan boiling. The large surface area allows rapid boiling off of water from syrups; Yoshida & Koyama (*1*), p. 213, fig. 5.

wall partition separated the furnace feeding side of the oven from the cooking platform side on which the cooking vessels were located.[a] This indicates that in the north to which this text refers, officials promoted sugar-making operations as a domestic household industry rather than as a 'factory' operation.

By the time of the *Thien Kung Khai Wu* of +1637, sugar making had long since moved out of the household situation, and artisans arranged boiling pans in a triangle, with a common heating source:[b]

> In boiling juice for sugar, three boiling pots should be arranged in the shape of a triangle (*ju phin tzu*[1]). First of all, transfer the thick syrup [that has been boiled in all the pots] into a single pot. Then gradually add more thin juice (*hsi chih*[2]) into the other two pots. If the force of the fire lacks even one hand full of fuel wood, the syrup (*thang*[3]) will form a poor quality sugar (*wan thang*[4]) with much foam that will not be of use.

This procedure continued until the 19th century when the British missionary the Rev. John Scarth described a, 'triple boiler, each of the pans spreading from a common centre like a clover leaf' in Swatow.[c]

The nature of the furnace and arrangement of the pots can be better understood by examining Georg Everhard Rumpf's *Herbarium Amboinense*, one of the

[a] Mazumdar (1), p. 144: Hommel (1), pp. 147–8.
[b] *TKKW*, pp. 167–8.
[c] Scarth (1), p. 49.

[1] 如品字 [2] 稀汁 [3] 糖 [4] 頑糖

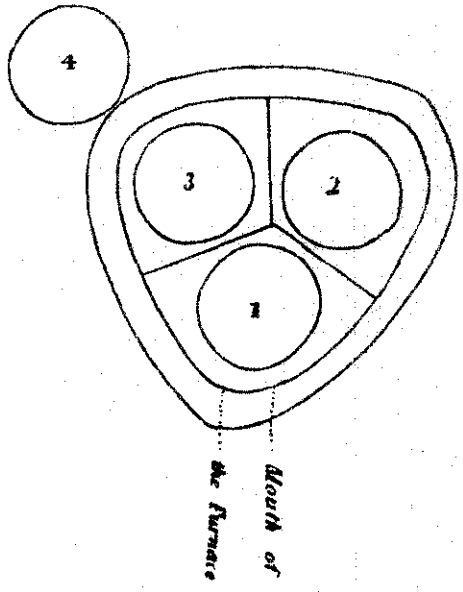


Fig. 100. A plan drawing of a Chinese boiling train operating in Hawaii during the 1830s. It clearly illustrates the Chinese evaporation process. Pan 1 was used for clarification while pans 2 and 3 served as evaporators. Syrup was concentrated in pan 3 and removed to cool in pan 4. The evaporation pans had a capacity of about 20 gallons each, and their volumes were extended by brickwork about two feet above the pan rims. The masonry extended down to ground level encompassing the furnaces, thus forming an enclosed unit which contained all heat generated; *Hawaiian Spectator* II, January 1839 in Kai (1), p. 71.

greatest works of pre-Linnean botany. He described Chinese methods of cultivation and manufacture in the Indonesian Archipelago during the late +17th century:[a]

Cut stalks with leaves removed are pressed between two rollers constructed from hard 'Cussambi' wood which are turned by cattle. Then the clear juice is taken away in channels, constructed from cut cattle hide, into large vessels for boiling. These vessels have a lower part of iron [i.e. the pan] which is joined to the oven. On the other hand, the top part of the boiling pan is built up with burnt stones which extend high so that the whole is seen to be a large boiling pan.

To this then juice is introduced and a strong fire built up. As the syrup diminishes new juice is added slowly, and the fire is eased until the juice becomes dark and thick.

Perhaps the most detailed account of the arrangement of Chinese furnaces and pans as observed in Hawaii appeared in the *Hawaiian Spectator* II, of January 1839 (see also Fig. 100):[b]

The evaporating pans contained about twenty galls. each and were set triangularly thus; (fig. 2) the furnace was built of sun burnt bricks, 18 inches long 9 wide and 6 thick. These bricks (if they can be so called) are made of common earth, hens 'feathers, goats' hair, hogs' bristles, and water, and laid up with the same compound; the

[a] Rumphius (1), vol. 5, p. 188.
[b] Appended to Kai (1), p. 70–2.

mouth of the furnace was about two feet high by one foot wide, and directly over it was a small hole to allow the smoke to pass off. The capacity of the pans was increased two-fold by extending the brick work two feet above the rims; this brick work was protected from the action of the syrup (at least for a time), by being covered with mats, tapas, banana leaves, lime, brick dust, etc.

Pan No 1. (fig. 2) seemed to be used for a clarifier only, and was separated from the other two by boards, projecting from the brick work to a common centre. Pans 2 and 3 served for evaporators and when the ebullition was great, flowed into each other; this was prevented by, occasionally, throwing in a small quantity of an offensive, greasy preparation, the principal ingredient of which is the *lees* of ground nut oil.

The syrup was concentrated in pan 3, thence removed to cooler 4.

Brick extensions around the boiling pans mentioned by Rumpf and described in detail in Hawaii were characteristic of Chinese sugar boiling pan arrangements from the +17th century. They served the following important functions; they (1) conserved heat, (2) extended the effective volume capacity of the pan (because it could be filled up to the rim) and (3) prevented loss from frothing over.

In the West, de Bry in +1595 (see Fig. 63) and Stradanus in +1585 (see Fig. 70) showed open fires heating juice in deep pots. Mazumdar noted the similarity between Deerr's first evidence of an evaporation train in a painting of a scene in Brazil appearing in Barleus in +1648 and the account in the *Thien Kung Khai Wu*.[a] The boiling pan arrangement depicted in Piso & Margrav demonstrated the same point (see Fig. 101). In the New World this innovation of pans built into the masonry to conserve heat, and with the additional sharing of a common fire, became known as the Dutch oven and later the French and Jamaica trains.[b] Mazumdar suspected a connection with China, but could see no obvious avenues for transmission as she was not aware of the Chinese involvement in sugar making in the Dutch-controlled parts of the Indonesian archipelago. Rumpf provided additional information on the construction, and described a single oven which was more common in the Chinese sphere of influence. This brings us to a most interesting point concerning technology management. The Dutch oven or Jamaica train (see Fig. 102) with pans set in a single line has been hailed as a major invention by most historians, because of its capacity to heat several pans at once. Manuel Moreno Fraginals offered a different perspective:[c]

When the shortage of firewood finally became critical in the Havana-Matanzas area, the sugarocrats returned to the 'French train', but named it the 'Jamaica train' because they were then copying from Jamaica. It was an unashamed step backward. Only our historians' total ignorance of sugar technology accounts for the assertion, maintained down to our time, that the Jamaica train was an 'innovation'. Facing the same primitive problem of timber shortage with the same primitive slave-labor system, Cuba resorted to an old Antillean solution.

[a] Mazumdar (1), pp. 146–7, Deerr (1), p. 556 and pl. 8, see also Deerr & Brooks (1), p. 1.
[b] Mazumdar (1), p. 146, Fraginals (1), p. 39.
[c] Fraginals (1), p. 39.

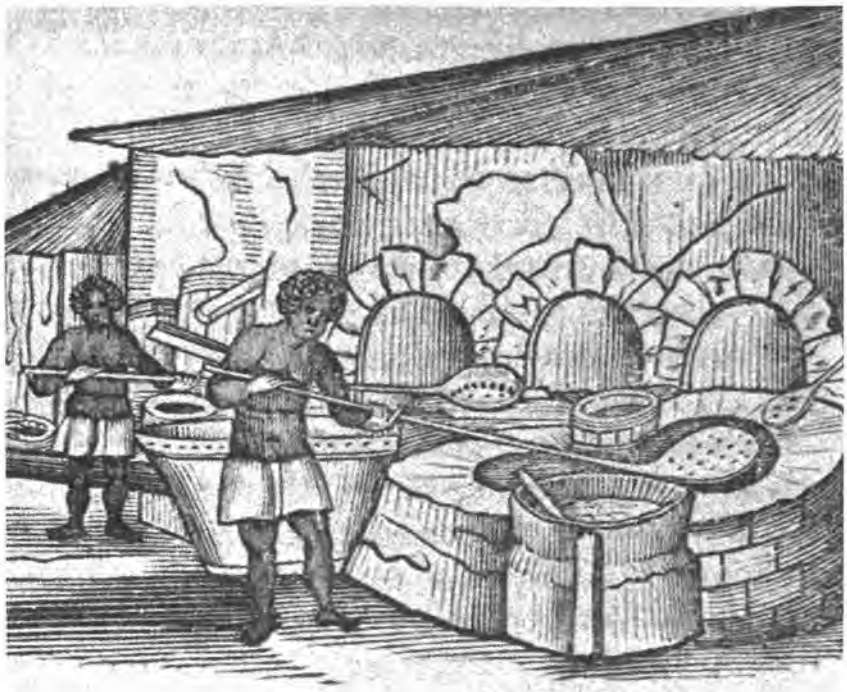


Fig. 101. A sugar boiling unit in +17th-century Dutch Brazil showing the skimming operation. The boiling pans were completely enclosed in masonry, and greatly resembled the Chinese method of placing boiling pans. The *Thien Kung Khai Wu* of +1637 and Rumpf in his descriptions of Chinese operations in the Dutch East Indies in his *Herbarium Amboinese* related that the Chinese arranged pans with enclosed masonry which extended two feet above the rim of the pans; Piso & Margrav (1), p. 51. I have hypothesised a technological transfer between these areas.

Fraginals does his reader the courtesy of assuming a technical competence that the Cuban historians lacked. I suggest the following deficiencies with the linear arrangement of pans fired by a single furnace. First, it limited rates because single fires boil off water more quickly, but with good management little extra fuel was required. Second, operators exercised less control over the whole boiling process. Operations of clarification, evaporation and crystallisation which were completed sequentially in a single pan, get confounded when spread over continous operations in a small number of pans in a train, leading to poorer quality sugar.[a] In the Chinese context it is significant that single pans were mostly employed as many of the mills were portable. The Chinese found it more convenient and economical to stay with the single fires, and higher production rates.

The only exception comes from Nei-Chiang county[1], Ssu-Chhuan, during the 20th century where researchers observed two kinds of boiling arrangements

[a] Porter (1), pp. 88–92.

[1] 內江縣

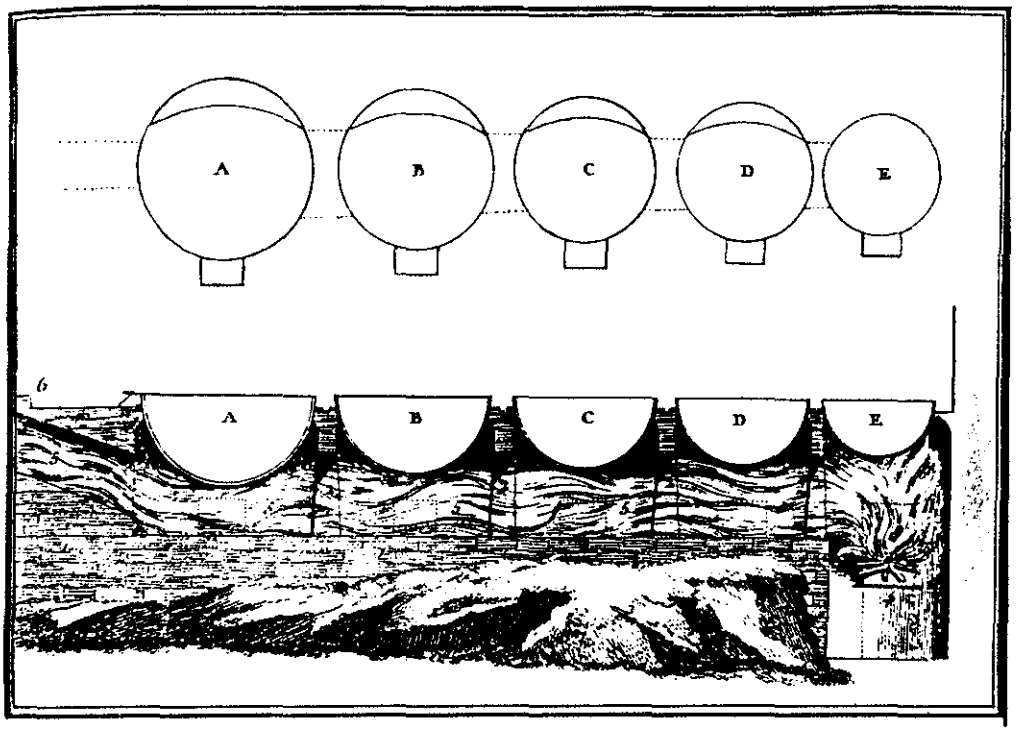


Fig. 102. A Jamaica train from the +18th-century West Indies, most probably Haiti. Juice was introduced into pan A. As syrup became progressively concentrated it was transferred up the line to pan E where the sugar was crystallised. A common variant was to have two smaller finishing pans E. A single fire heated all the pans. These pan arrangements were alternatively known as Dutch ovens, or French and Jimagua (Jamaica) trains; the *Encyclopédie* of Diderot through Gillispie (2), pl. 40, Sugar IV.

with ten or more pans over a single fire furnace. The most popular kind, known as the spear furnace (*chhiang tsao*[1]), comprised ten or more pans set in a straight line, while the other, called the flower furnace (*hua tsao*[2]), had eight pans in a row with two pans on either side of the first two arranged in the shape of a cross, exhibiting the appearance of a flower with four equal petals arranged crosswise (*Cruciferae*). The single fire furnace was enclosed within masonry, and constructed at an angle of 7 per cent to the level facilitating the heating of all the ten pans.[a] This type of furnace could possibly have been introduced from India in the late Thang or Five Dynasties periods as the Tun-Huang document p. 3303, dating from the 9th to 10th centuries, mentioned an arrangement of fifteen boiling pans,[b] and an ascending furnace adopted from Chinese pottery kilns (see Fig. 103).

In large 20th-century factories, the evaporation segment is completely separated from the crystallisation process. The juice is 'heavied up' to about 60 per

[a] Kanda (*1*), pp. 533–4 and Than (*1*), pp. 144–7.
[b] Chi (*1*), pp. 124–5. This document is translated and discussed below, see pp. 373–7.

[1] 槍灶 [2] 花灶

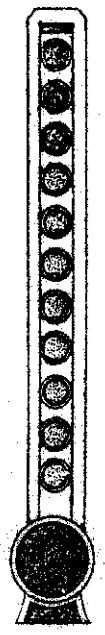


Fig. 103. A drawing of an evaporation train in early 19th-century India. A row of 11 earthen boilers were connected underground with a flue modelled in clay. The flue extended to the bottom end where there was a large boiling pan and a furnace. The common fire heated all pans. Juice was moved successively from pan 1 to pan 11 becoming increasingly concentrated as boiling continued. The massecuite formed in the final large iron pan. The 15 pan arrangement described in the Tun Huang document P 3303 is surely the predecessor of this later arrangement. I also suggest that the idea from the Indian 'train' could have been transferred to the French and English Western Indian colonies as the Jamaica train; East India Company (1), p. 25.

cent solids or more in triple or quadruple effects, and stored in tanks for undertaking the crystallisation process, in separate vacuum pans later.[a] In pre-modern technology the evaporation stage terminated in crystallisation in the last pan, or alternatively in the single boiling pan. The determination of the correct striking point still remains the central part of the mystique of sugar-boiling. Good sugar boilers are still highly prized and well-paid employees today, even though instrumentation, such as conductivity equipment, have added science and lessened the need for art. Detailed instructions on how to ascertain the striking point are scarce in Chinese sources. In putting this matter in perspective, we should note first of all that when making concrete or amorphous sugar, the striking point was not critical. Artisans continued boiling until the syrup became so thick that they could see that the sugar was about to set hard. It was only when they began to make true massecuite, with large crystals from which syrup can be drained, that the striking point assumed importance. The judgement of the precise point was not infallible because they were not dealing with pure sucrose solutions; the impurities that affected the saturation of sucrose varied in kind and quantity. Artisans aimed to get a syrup oversaturated to the degree that the sucrose crystallised out surrounded by a syrup of the right

[a] Spencer & Meade (1), ch. 11.

density and this enabled the draining of the syrup from the crystals in a cone.[a] It was also necessary for the sugar crystals to be sufficiently uniform in size to make drainage of syrup possible.[b]

Sugar boilers devised methods of determining the correct point to cease boiling. They included the appearance of the boiling syrup, 'feel' of the syrup between the fingers,[c] a test of stickiness by how far 'threads' can be drawn out from a test sample,[d] directing drops into cold water until they turn hard.[e] Chinese texts acknowledged the necessity of obtaining the correct point but rarely defined the procedure. Once again the *Thien Kung Khai Wu* is our principle source:[f]

> Watch the bubbles in the boiling juice to regulate the force of the fire (*khan shui hua wei huo sê*[1]). When the boiling bubbles turn fine and delicate, like those in boiling soup, test it by touching with the fingers. If [the syrup] sticks to the hand you know it has come [to striking point].

Dutrône la Couture in +1790 took the first step in implementing scientific control over boiling when he discovered that the elevation in the boiling point of cane syrup above 212°F was proportional to the concentration of sucrose. He compiled an empirical table that sugar boilers followed for almost the next hundred years. His routine practice was to strike at 228–229°F for muscovado, and to strike at 234°F if making clayed sugar.[g] The *Thai Hai Shih Chha Lü* of +1736 remarked on the importance of temperature in selecting the striking point:[h]

> For boiling sugar it is essential to find a sugar master (*thang shih*[2]) who is an experienced person, and is skilled in judging the optimum boiling temperature for striking (*chih thu mai ching huo hou*[3]).

This text demonstrated that some Chinese realised the crucial role of temperature in sugar boiling.

There were two other crystallisation points for manufacturing speciality sugars, which I will discuss in detail below, but should be mentioned at this stage. Artisans boiled the syrup to a lower concentration in making *sha-thang* (sand sugar) and *thang-shuang* (sugar candy). *Sha-thang* had soft crystals em-

[a] Modern research indicates that a supersaturation coefficient of 1.25 to 1.40 is ideal. At this level of supersaturation existing crystals will grow without the continuous formation of new grain, see Spencer & Meade (1), pp. 181–2.

[b] Modern sugar manufacturers aim to obtain (1) the formation of the required number of crystals, (2) growth of optimum crystal number without introducing too many new ones, and (3) finally to exhaust the syrup in growing the desired crystal size.

[c] Watt (1), vol. 6, pt 2, p. 295.

[d] Edwards (1), vol. 2, p. 236.

[e] Watt (1), vol. 6, pt 2, p. 308.

[f] *TKKW*, p. 169.

[g] Dutrône la Couture (1) is a rare text in libraries apart from France, however, Porter (1), pp 84–132 and pls. 2 and 3 gives an extensive exposition of Dutrône la Couture's ideas and methods. Also see Porter (1), pp. 117–18 for boiling temperatures of muscovado and clayed sugar. Florens (1) made the first revision of Dutrône la Couture's table of boiling point elevation in 1876.

[h] *THSCL*, p. 56.

[1] 看水花爲火色 [2] 糖師 [3] 知土脈精火候

bedded in syrup made by beating slightly supersaturated syrup with paddles, and utilised the heat of crystallisation to evaporate water. The procedure comprised beating the syrup and applying further heat to the syrup if no crystallisation resulted. For *thang-shuang*, the syrup was boiled to about saturation point and the syrup cooled with bamboo slips added to provide sites for crystal nucleation. In this case the accuracy of judgement did not prove critical in cold climates, as the syrup became increasingly supersaturated as winter progressed.

(6) Refined Sugar Products: Crystallisation

(i) *Introduction*

With crystallisation, we come to the last operation in the sugar-making process. The great array of names for sugars, none of which seem to be standardised, become the first major obstacle for researchers. Sir George Watt complained about the incomprehensible range of sugar grades in 19th-century India.[a] In the medieval Mediterranean Francesco di Balduccio Pegolotti named sixteen forms.[b] Germaine Cosiva found nineteen kinds in French supermarkets during the 1970s,[c] and a quick count shows over a dozen in 19th-century China. These names mean very little as the same grade of sugar can be produced by two or more entirely different processes. For instance, good white sugar can be made by superior clarification and indifferent crystallisation, or alternatively by minimum clarification followed by careful crystallisation and drainage. The only systematic way to examine the problem is to enumerate the technologies and then indicate the grades of sugar they are capable of making.

(ii) *Outline of crystallisation technologies*

General terminology in China recognised four main classes of sugar manufactured by different technologies. The products were in reality a graduation of crystal size:

1 *amorphous (concrete) sugar* (*shih-mi*[1]) made by boiling syrup to low water content. It appears to be amorphous but small crystals are apparent under microscope.
2 *soft brown sugar (sha-thang*[2]), a sugar which is soft because of very small grains set in syrup; made by rapidly beating sugar at graining point. This is a modified massecuite, and is remarkable for the speed with which it dissolves in the mouth.
3 *massecuite, black sugar* (*hei-thang*[3]) which has larger crystals set in syrup; made by stirring syrup slowly at graining point.

[a] Watt (1), vol. 6, pt 2, p. 254.
[b] Lopez and Raymond (1), pp. 109–14.
[c] Cosiva (1).

[1] 石蜜 [2] 沙糖 [3] 黑糖

4 *sugar candy* (*thang-shuang*[1]), large crystals of dry sugar, made by prolonged growth of crystals formed by using bamboo slips as centres of crystal foci.

All these classes were consumed or marketed in their own right. Three technologies, not discussed as yet, enabled the manufacture of further grades.

1 *Syrup drainage.* In the case of massecuite (*hei-thang*[2]) the syrup could be drained off in a cone which resulted in a dry sugar, called muscovado in the British colonies in the Caribbean. Muscovado was not widely prepared in China, Brazil and the French Caribbean, the major sugar-producing countries of the +17th and +18th centuries. In China sugar-makers called it *lou tshai*[3] in Taiwan and *thang-chhing*[4] in Ssu-Chhuan, and usually never marketed it, but always clayed it to make white sugar.

2 *Claying.* A layer of moist clay was placed on top of the massecuite (*hei-thang*[2]) in a draining cone, and left for about thirty days to allow the water from the clay to flow down over the crystals, washing off the syrup. This resulted in very white sugar at the top of the cone with darker sugar below. The generic name for clayed sugar was white sugar (*pai-thang*). Makers graded *pai-thang* into top, middle and bottom classes, the sugar at the top of the cone was the whitest and that at the bottom the darkest. The names varied with locality, and claying served as a major means of manufacturing export quality sugar in the Chinese sphere of influence, Brazil and the French colonies.

3 *Reboiling.* Drainage separated the major portion of the impurities from the sugar. Even higher grades could be made by reboiling drained or clayed sugar because the major impurities had already been separated in the first crystallisation and drainage. It was common to reboil, reclarify, crystallise and drain to make very high quality sugars for special purposes such as moulding animal forms. Artisans undertook several re-boilings with progressive increases in purity.

With this background we can now examine the history of these technologies.

Ancient Indian technology

Ancient India was without a doubt the first cultural area to make sugar products. The *Pātimokkha*, the initial rules of the Buddhists, codified in Sakayamuni's own lifetime c. −500, mentioned syrup (*phāṇita*) which was allowed to sick monks as one of the five medicines. Amorphous sugar (*guḍa*) appeared about −300 in the expanded version of the rules, the *Vinaya*.[a] Traditional Hindu lit-

[a] Thomas (1), p. 15 supported Oldenburgh (2), vol. 1, p. xv with evidence that the *Pātimokkha* (in Pali, *Prātimokṣa* in Sanskrit) was codified in the Buddha's own life time or that of his own personal disciples, i.e. c. −500. The *Pātimokkha* is most readily studied in the *Vinaya* which included the commentaries. The *Vinaya* texts have been published in Pali in Oldenburgh (2) and translated by Horner (1). For *phāṇita* and the five medicines see: Oldenburgh (2), vol. 3; p. 77 and Horner (1), vol. 1, p. 133; for *guḍa* (*guḷa* in Pali) see Oldenburgh (2), vol. 1, pp. 210, 226 and Horner (1), vol. 4, pp. 285, 308.

[1] 糖霜 [2] 黑糖 [3] 爾菜 [4] 糖清

Table 15. *Sugar products in ancient India*

(i) *phāṇita*	syrup
(ii) *guḍa*	amorphous sugar or crystalline *gûr*
(iii) *matsyaṇḍi*	massecuite (syrup & crystals)
(iv) *khaṇḍa*	higher grade sugars, purified by unknown methods
(v) *śarkarā*	
(vi) *sitopalā*	sugar candy

erature supported this dating; *guḍa* featured in the *Baudhāyana*, one of the four main *Dharma sūtras*, indicating a later date than the generally accepted time scale of −600 to −200 for sutra literature.[a] During the following three hundred years Indians learnt considerably more about sugar manufacture. Three additional products, *matsyaṇḍi*, *khaṇḍa*, and *śarkarā*, emerged in the *Arthaśāstra* (−100). *Caraka Saṃhitā* (+1st to +2nd century) and *Śuśruta Saṃhitā* (+4th century) variously dated from −100 to +300.[b] I consider the +1st century the best estimate for dating these sugars.[c] *Sitopalā*, or sugar candy, appeared in the Bower manuscript of c. +375,[d] and this ends the inventory of ancient Indian sugars. To date it has not been possible to determine exactly how all of these sugars were made, but all authorities agreed on the following ascending order of purity: *phāṇita*, *guḍa*, *matsyaṇḍi*, *khaṇḍa*, *śarkarā* and *sitopalā*. Jorges Chandra Ray, an early 20th-century scholar and scientist, summarised information for identifying them (see Table 15).[e] I agree with Ray's identification, and later cite some Chinese texts to verify that *khaṇḍa* and *śarkarā* are soft brown sugars and white crystalline sugars respectively.

The technological mission to India in the mid +7th century.

Many scholars have tried to determine when the Chinese first began to make crystallised sugar. Despite some exceptions,[f] it is generally agreed that the art of making crystallised sugar was not originally a Chinese invention, but came from outside, most probably from India. Chinese scholars of the Sung,[g] Japanese scholars of the Edo period[h] and finally the Europeans, Ritter,[i] von Lippmann,[j] Deerr,[k] and others[l] all subscribed to the idea that a technological mission sent

[a] Sugarcane (*ikṣu*) occurred in all the four major *Dharma sūtras* (*Apastamba*, *Vāsishtha*, *Gautama*, and *Baudhāyana*) but sugar (*guḍa*) only appeared in *Baudhāyana* 1, 5, 12, 3 and 14. See Bühler (1).

[b] Ray, J. C. (1), pp. 439–40. For datings of the *Arthaśāstra*, *Caraka Saṃhitā* and *Śuśruta Saṃhitā* see Winter, H. J. J. (1), pp. 145, 149 and 150 respectively.

[c] This dating is also supported by the fact that the first mention of sugar as a trade commodity appeared in the *Periplus Maris Erythraei* which is dated at +60 to +70 in Shitomi (1).

[d] Dating from Winter, H. J. J. (1), p. 149. *Sitopalā* was also mentioned in the *Suśruta Saṃhitā*. See Monier-Williams (1), p. 1214.

[e] Ray, J. C. (1), pp. 441.

[f] For instance see Liu & Huang (1), p. 5.

[g] For example Lu Yu see Tai (1), p. 84.

[h] Gotō Rishun in his *Kansha Kō*.

[i] Ritter (1), pp. 358–9.

[j] von Lippmann (4), p. 259.

[k] Deerr (1), p. 35.

[l] Hirth and Rockhill (1), p. 113 and Tai (1), pp. 18–19.

to India in the mid +7th century by Thai-Tsung[1], the second Emperor of the Thang dynasty, introduced the art to China. Yet, as we have seen earlier, the Chinese were already boiling low-grade amorphous sugar by about +400.

The implications of this technological transfer have great bearing on the later history of sugar in China, so it is imperative to obtain a clear idea of its role from the start. Let us first examine the sources upon which these claims are based. Most scholars cite the following passage concerning Magadha in the *Hsin Thang Shu* which was compiled in +1061:[a]

In +647 [Magadha] sent an envoy for the first time to communicate (*tzu thung*[2])[b] with the Son of Heaven presenting the bodhi tree (*po lo shu*[3]),[c] a tree resembling the poplar (*pai-yang*[4]).[d] Thai-Tsung despatched an envoy to obtain the method of boiling sugar (*ao thang fa*[5]) and instructed that sugarcane (*chu chê*[6]) be submitted from Yang-Chou[7]. The juice was [extracted by] pressing (*cha*[8]) [in a mortar][e] as if [preparing] a dosage of [medicine]. It far surpassed that of the Western regions in colour and flavour.

Another important source, the *Thai-Phing Yü Lan*[9] (Thai-Phing Reign Period Great Encyclopaedia) of +983, related the same event in a slightly different way, albeit without specifying the Emperor who ordered the mission or the date:[f]

The *Thang Shu*[10] records; The [Western] barbarian and Hu countries produce *shih-mi*[11]. China highly prized it, so the Emperor despatched an envoy to Magadha (*Ma Chia Chhih Kuo*[12]) to obtain the method of making it, and ordered that the juice of the sugarcane (*chu-chê*[6]) be boiled in the kitchen at Yang-Chou[7] and that they make [the sugar] themselves. It far surpassed that of the Western regions in colour and flavour. The Em-

[a] *Hsin Thang Shu*, p. 6239.

[b] This could also be read as *tzu* [*tzhu*] *thung*[13] literally from this communication.

[c] R 596, listed *po lo shu*[3] as the Jack fruit tree, but this identification is erroneous since in the *Tshê Fu Yüan Kuei*, p. 1140 it is recorded that on this occasion Magadha presented 'the Bodhi tree' (*phu-thi shu*[14]), also called the *po-lo*[15], the leaves of which resemble the poplar (*pai-yang*[16]). The bodhi tree is classified as *Ficus religiosa* L., and as such would a suitable gift from a Buddhist ruler. It was possibly a clone of the tree under which the Buddha attained enlightenment.

[d] R 623.

[e] The character *cha*[8] is interchangeable with *tsan*[17]. It is interesting to note the similarity of this account of the juice extraction process and the description given in the Tun-Huang manuscript reproduced in Chi (*1*) p. 125. Lines 3–4 of the latter document read: '*chhu tsao chih shih. chhü kan-chê ching, chhi chhüeh shao yeh, wu-tshun chieh tuan, cho ta mu chiu, niu chuai [or yeh] tsan chhu chih*[18]. (When making [sugar] first take the stalks of sugarcane, remove the tops and leaves, cut them into [lengths] of five *tshun* [15cm] and put them into a large wooden mortar. The oxen drags [a pestle] and the juice is pressed out.)' This passage described the Indian process of crushing sugarcane in a *kolhu*.

[f] *Thai-Phing Yü Lan*, ch. 857, p. 2a. The same passage with minor differences in the wording appeared in the *Tshê Fu Yuan Kuei*, p. 1140 under the entry for the third lunar month of +647.

[1] 太宗 [2] 自通 [3] 波羅樹 [4] 白楊 [5] 熬糖法
[6] 諸蔗 [7] 揚州 [8] 拃 [9] 太平御覽 [10] 唐書
[11] 石蜜 [12] 摩伽池國 [13] 自[此]通 [14] 菩提樹 [15] 波羅
[16] 百楊 [17] 拶
[18] 初造之時、取甘蔗莖、棄却根葉、五寸截斷、着大木臼、牛拽、拶出汁

peror Kao-Tsung[1] [r. +649 to +683] again despatched Wang Hsuan-Tshê[2] to this country to erect a stone tablet there at the Mahābodhi temple (*Ma Ho Phu Thi*[3])[a]

This source, written before the *Hsin Thang Shu*, gave the reason for sending the envoy to Magadha as specifically to learn the art of making *shih-mi* which the Chinese valued highly. The *Hsin Thang Shu* only recorded sugar boiling whereas the *Thai Phing Yü Lan* mentioned *shih-mi*. There were two possible sugars that the Chinese could have learnt to make from India, *sha-thang* and *shih-mi*. The Tun-Huang manuscript cited below indicated large differences between *sha-thang* and *shih-mi*; the former was first-boiled soft sugar made by beating supersaturated syrup, while the latter was second-boiled hard-grained sugar obtained by melting *sha-thang*, clarifying, crystallising and draining.

The sequence of events in these two passages was most important; Magadha first sent an envoy to Thang China to present gifts, and then Thai-Tsung despatched a Chinese envoy to learn the art of sugar boiling. The *Tshê Fu Yüan Kuei*[4] of +1013 also recorded that Magadha submitted a Bodhi tree (*phu-thi shu*[5]) to the Thang court as an article of tribute in the third lunar month of +647, and furnished an account of the technological mission to India under the same entry.[b] Given that the Chinese valued *sha-thang* so highly, it is plausible that they may have taken the opportunity of sending a mission back with the Magadhian envoy to ensure that they received the technology. Before proceeding any further let us examine other available evidence on the subject.

Recently the Chinese historian of Sino-Indian relations, Chi Hsien-Lin, has drawn attention to the following passage in the *Hsü Kao Sêng Chuan*[6] (Further Biographies of Eminent Monks) of +660, which sheds further light on the subject. In the biography of Hsüan-Chuang[7] (+602 to +664), the famous Chinese pilgrim who visited India during the early Thang dynasty we find:[c]

[King] Harsavardhana (Chieh Jih [Wang[8]]) and the monks each despatched secret envoys (*chung shih*[9]) to carry the various *sutra* treasures to present to China (*Tung Hsia*[10]) from afar. This was brought about by the envoys from India coming after Hsüan Chuang [had visited that country] and declared the way of the Emperor. After the envoy [from King Harsavardhana] returned to the West again, Wang Hsüan-Tshê[11] and twenty other people were ordered by Imperial decree to follow [the returning envoys] and to proceed to Bactria (*Ta Hsia*[12]) [thence to Magadha]. They were presented with over a thousand bolts of silk (*ling po*[13]) [as gifts for use on their travels]. Wang and the same number of monks each having their own assignments went to the Bodhi-vihara temple (*Phu Thi Ssu*[14]) [in Magadha] where the monks summoned *shih-mi* artisans (*shih-*

[a] This lends credence to the possibility that the bodhi tree presented to Emperor Kao-Tsung was a clone of the tree, under which the Buddha reputedly gained enlightenment at the Mahābodhi temple.

[b] *Tshê Fu Yuan Kuei*, p. 1140.

[c] *Hsü Kao Sêng Chuan*, ch. 5, p. 7a. The same text is also in *Taishō Shinshū Daizōkyō*, vol. 50, no. 2060, p. 454, bottom. Chi (*1*), p. 135.

[1] 高宗 [2] 王玄策 [3] 摩訶菩提 [4] 册府元龜 [5] 菩提樹
[6] 續高僧傳 [7] 玄奘 [8] 戒日王 [9] 中使 [10] 東夏
[11] 王玄策 [12] 大夏 [13] 綾帛 [14] 菩提寺

mi chiang[1]), and thereupon despatched two [*shih-mi*] artisans and eight monks who all went to China (*Tung Hsia*[2]). An Imperial decree was requested [for them] to proceed to Yüeh-Chou[3] where they made it [*shih-mi*] using sugarcane. Everything was successfully accomplished.

This source revealed further information concerning the date of the technological mission and details of its organisation. First let us consider the question of dating. The *Hsin Thang Shu*[4] recorded that Thai-Tsung sent an envoy to Magadha after the first visit of an emissary from that country in +647.[a] Since the *Hsü Kao Sêng Chuan* also mentioned that the Chinese envoy was despatched following the visit of an Indian emissary who came after Hsüan-Chuang returned from India in the first lunar month of +645, we can conclude that both texts referred to the same Chinese envoy that left China in +647. Wang Hsüan-Tshê served as the principal envoy on this occasion, his second mission to India.[b] Most scholars have accepted +647 as the date for the technological transmission assuming that the Chinese envoy left and returned in the same year. The truth of the matter was that when Wang Hsüan-Tshê arrived in India he discovered a considerably changed situation; the death of King Harsavardhana, who had united northern India after the disunity following the Gupta period and remained on the throne since +606, had thrown India into a state of turmoil. He made a name for himself by borrowing 1,200 troops from Tibet (*Thu Fan*[5]) and 7,000 cavaliers from Nepal (*Ni Pho Lo*[6]), and bringing about a peaceful settlement. He returned to Chhang-An[7] in the fifth lunar month of +648 with the Indian captives.[c] With the Indian kingdoms preoccupied with war it seems very doubtful that there would have been any opportunity for leisurely technological transfer at the State or diplomatic level. Indeed, Wang himself would have been so busy fighting that it is hard to imagine him concerning himself with the intricacies of sugar making.

In regard to this problem, the *Hsü Kao Sêng Chuan* offered a possible solution: transmission by Buddhist monks. This source makes it clear that the Buddhist monks accompanying Wang on the mission despatched two *shih-mi* artisans together with eight monks from Magadha back to China. The two *shih-mi* artisans,

[a] This was not the first envoy from Magadha as the *Chiu Thang Shu*, p. 5307 recorded that an emissary from King Harsavardhana came to China to submit tribute in +641. Also see Feng (*3*), p. 3.

[b] Wang Hsüan-Tshê made a total of three trips to India, see Fêng (*3*). pp. 3–4. On the first trip, in which he served as vice envoy, he left China in +643 and returned in +646. On the second trip which left China in +647 he served as principal envoy. The third trip lasted from +657 to +660. For the reasons given in the text above and since the passage in the *Hsü Kao Sêng Chuan* specifically stated 'again Wang Hsüan-Tshê and twenty other people were ordered by Imperial decree to follow [the returning envoys] and to go to Bactria' we can be certain that this was not the first trip undertaken by Wang Hsüan-Tshê. Also note that the third trip would have been almost too late for this event to have been included in the *Hsü Kao Sêng Chuan* which was completed in +660. For studies which bring together the scanty information available about Wang Hsüan-Tshê see Lévi (*1*) and Fêng (*3*).

[c] Feng (*3*), pp. 3–4 and Levi (*1*), pp. 301–2.

[1] 石蜜匠 [2] 東夏 [3] 越州 [4] 新糖書 [5] 吐蕃
[6] 泥婆羅 [7] 長安

who transferred the technology to China, may have been sent back before Wang, but in any case the date for the transfer should be +647 to +648.

Yet judging from the monks, as well as Wang, 'each having their own assignments' and from the fact that the sugar making in Yüeh-Chou,[a] was conducted with Imperial approval, it is evident that this case of technological transfer was undertaken at the State level as far as official Chinese chroniclers were concerned. The *Hsin Thang Shu*, *Thai-Phing Yü Lan* and the other standard sources naturally emphasised the Emperor as the main motivating force behind technological transmission. The *Hsü Kao Sêng Chuan*, the only independent source, indicated that Buddhist monks undertook the actual transfer of sugar technology. The first line of the *Hsü Kao Sêng Chuan* passage confirmed that Indian monks, as well as Indian Kings, despatched emissaries to China. The monks probably desired to ingratiate themselves with the Chinese Emperor and the upper echelons of society, in the hope of promoting Buddhist missionary activities in China. Demonstrating the art of making sugar, an article imported from the Western regions in great demand at the Chinese court, would have been a natural way of trying to achieve this end. Perhaps Matteo Ricci was merely following in the footsteps of Buddhist monks in presenting technological marvels of the West to the Ming court. In addition, the close association of sugarcane and sugar with Buddhist doctrine as seen earlier also constituted another motive.[b] Whatever the reason, the importance of the participation of Buddhist monks was that they possessed the ability to disseminate sugar-making technology over a far wider section of Chinese society, through their estates, monasteries and connections with the aristocracy, than the Emperor who might want to reserve it for his own kitchen.[c] This Buddhist element made it something more than a simple case of Imperially motivated technological transfer.

In summary the so-called technological mission was undertaken by Buddhist monks in the entourage of Wang Hsüan-Tshê, the official envoy who left China in +647. Acquiring the art of making sugar constituted only one of the many tasks assigned to the envoy. It may be regarded as a Buddhist-inspired case of technological transfer that could have been followed by further exchange for evangelistic purposes which eluded documentation for posterity.

[a] The *Hsü Kao Sêng Chuan* account differed from that given in the other three sources in regard to where the sugar was made. The former source recorded Yüeh-Chou (Shao-Hsing in Chekiang province), but did not mention sugarcane submitted from Yang-Chou as stated in the others.

[b] See (b), pp. 59–62.

[c] The ability of agricultural processing technology to be disseminated on estates (*chuang-yüan*[1]) owned by the nobility is ably illustrated by the spread of water-driven *nien wei*[2] flour grinding mills in north China during the Thang dynasty. Though these mills seem to have existed from the Han dynasty they only came to be of historical significance during the Thang. Despite repeated government prohibitions against setting them up they spread as the cultivation of wheat became popular in north China under the system of growing three crops in two years. They symbolised the advent of this new cropping system as well as the changeover from the equal field land system (*chün thien fa*[3]) to the biennial tax system (*liang shui fa*[4]). See Nishijima (*r*), pp. 235–78.

[1] 莊園 [2] 碾磑 [3] 均田法 [4] 兩稅法

The Tun-Huang MS P 3303, on sugar making

Next let us try to ascertain exactly what type of sugar- making technology was transferred at this time. Chi Hsien-Lin has recently uncovered a new source concerning sugar technology transfer during the Thang, a fragmentary document of less than several hundred characters from Tun-Huang, Pelliot number P 3303. It was written on the back of a *sutra* manuscript, and is provisionally dated at the +9th to +10th centuries.[a] Despite containing erroneous characters and lacunae, it is of the highest importance, the earliest substantial account of sugar-making technology in China, and possibly the world. The manuscript is extremely significant for the light it throws upon the transmission of sugar technology from India to China via Buddhist monks during the Thang. The entire document translated from the edited and annotated version of Chi Hsien-Lin reads:[b]

Three types of sugarcane (*kan-chê*[1]) are produced in the five regions of India under the Western heaven (*hsi thien wu yin tu*[2]). The first kind [one character deleted] has a stalk (*miao*[3])[c] eight *chhih*[4] [2.5 metres] long and mostly not excellent for making *sha-thang*[5].

The second type is one or two *chhih* [31–62 cm] shorter than [the first type] and makes [one character deleted] good *sha-thang* and makes excellent *sha-ko-ling*[6] [*shih-mi*[7]].[d]

The third type is also good.[e]

When making [sugar] first take the stalks of sugarcane, remove the tops and leaves, cut them into [lengths] of five *tshun*[8] [15 cm] and put them into a large wooden mortar. The oxen drags [the pestle][f] and the juice is pressed out.

The juice is received in an earthenware jar (*weng*) and is boiled in fifteen pans (*chheng*[9]) [see Fig. 103]. Next drain [the boiled syrup] into a [cooling] pan and use chopsticks to add[g] a little [text does not mention of what].[h] After being completely cooled beat [the

[a] Mazumdar (1), p. 95.

[b] This translation was made from the reproduction of the original text given in Chi (*1*), pp. 124–5, and reference has been made to the supplementary notes provided in Chi (*2*).

[c] *Miao* means seedling, but here it must refer to the stalk.

[d] Chi (1), p. 132–133 interpreted *sha-ko ling* as *shih-mi*, the Chinese term for the Sanskrit word *śarkarā*.

[e] An Indian tradition of uncertain date denotes three types of sugarcane in India; *Paunda* (thick *S. officinarum*), *ganna* (medium sized) and *ik* (thin *S. barberi*) types, see Barber (4), pp. 139–40.

[f] Chi ((*1*), pp. 128 and 131) interpreted this to refer to crushing between millstones (*mo shih ya cha*[10]), but the text did not mention mill-stones. The description of a large wooden mortar driven by an animal suggests the Indian *kolhu*.

[g] The original has the character *thien*[11] which I read as *thien*[12]. *Thien*[12] is an equivalent for *thien*[13] to add. This may refer to some kind of testing, as in testing the temperature of the boiling juice, and may not refer to the addition of ashes or other clarifiers as Chi (1), p. 128 and pp. 131–2 suggested.

[h] Chi ((*1*), p. 128 and pp. 131–2) claimed that a small amount of ashes were added. He explained that since the Indians used ashes for juice clarification well before the Thang dynasty, and later Chinese texts such as the *TKKW* and the *Wu Li Hsiao Chih* mentioned the addition of lime as a clarifier, the word ashes must be interpolated here. But neither the text, nor the context, permits such an interpolation as this line refers to syrup that has been poured into a cooling pan after the completion of the boiling process. Ashes cannot be added as a clarifier at the cooling stage. Also the first mention of ashes for juice clarification in Chinese sources did not occur until the Yüan dynasty as demonstrated earlier (see pp. 351–2). Chi's source for India is the *Vinaya* I, 210, 1–12 which recorded the addition of flour (*pittham*) and ashes (*chārikam*) to *gula*. He cited Hinüber (1), p. 95 (*cont.*)

[1] 甘遮 [2] 西天五印度 [3] 苗 [4] 尺 [5] 沙唐
[6] 煞割令 [7] 石蜜 [8] 寸 [9] 鐺 [10] 磨石壓榨
[11] 頎 [12] 揃 [13] 顚

Table 16. *The identity of Indian and Chinese sugar products to c. +1200*

Explanation	English	Sanskrit[a]	Chinese
Syrup (cane juice evaporated)[b]	syrup	*phāṇita*	*chê-chiang*[1,c]
Microscopic crystals in syrup (hard)	concrete	*guḍa*[d]	*shih-mi*[2] (to +500)[e]
Small crystals with syrup	jaggery[f]	*guḍa*	*hei-thang*[3,g]
Larger crystals with syrup	massecuite	*matsyaṇḍi*	....[h]
Soft brown sugar, syrup included[i]	—	*khaṇḍa*	*sho-thang*[4]
Hard grain sugar, syrup drained	muscovado[j]	*śarkarā*[k]	*shih-mi*[2] (after +500)[e]
Syrup drained from massecuite[b]	molasses	*kṣāra*	*thang-shui*[5]
Very large crystals, syrup drained	sugar candy	*sitopalā*	*thang-shuang*[6,l]

The word *chīnī* is a common name for various grades of sugar in modern India. Scholars have interpreted this to indicate that the methods of manufacture derived from China. Ray, J. C. (1) refuted this explaining *chīnī* as a corruption of the Persian word, *shirini*, the sugar offered to the medieval deity *Satya-pir*.[m]

[a] I have reviewed the information in Ray, J. C. (1), Gopal (1) and Hinüber (1) along with the P 3303 manuscript discussed above.

[b] Syrup and molasses are often confused in the literature. Syrup is heavied up sugarcane juice, and was the earliest sugar product. After sugar became common, syrup was phased out as a product. Molasses is the remaining syrup drained from a sugar that has been crystallised. *Phāṇita* is often translated as molasses. Before drainage technology was invented by the −1st century, *phāṇita* can only be translated as syrup, not molasses.

[c] This term first appeared in the poem 'Chao Hun'' see Liu, Wu-chi (1) p. 30. Early Chinese translations of Indian Buddhist texts contain additional appellations. For example, they include *kan-chê chih chiang*[8] in Taishō no. 125 *Ekottarāgama sūtra* (Nanjio no. 543), p. 705/1 translated in +384 to +385. *kan-chê chiang*[9] in Taishō no. 1425 *Mahāsāmghika Vinaya*? (Nanjio no. 1119), p. 362/2 translated in +416, *hei shih-mi-chiang*[10] in Taishō no. 156 (Nanjio no. 431) p. 131/3 dated between +25 to +220. *Pan-mi*[11], lit. half honey, was listed as a product of Persia and India in the *Sui Shu*, p. 1857.

[d] Also called *guḷa*; ḍ and ḷ are interchangeable in Sanskrit. This sugar is also the *gur* of modern India, see Ray, J. C. (1), p. 642. The same name is applied to material where the crystals cannot be distinguished (concrete) as well as small-grained sugar with syrup coating that can be rolled into balls. The etymological origin of *guḷa* is said to be from *goḷa*, meaning ball in Sanskrit, *ibid.*

[e] The term *shih-mi* initially referred to concrete sugar products made by a sun-drying process. Later the meaning changed. Before the commencement of the Sui dynasty in +581, sugar, probably the *śarkarā* of India, was imported from Persia, and the term *shih-mi*[2] referred to this product, see Laufer (1), p. 376. It was made in China after the so-called 'technological mission' of +647.

[f] The word jaggery passed into English from the Portuguese *jagara, jagra*, which is a corruption of *śarkarā* via a Malayan language. Jaggery referred to raw sugar made from palms as well as sugarcane. It was applied to palm sugar first, see Yule & Burnell (1), p. 446.

[g] *Hei-thang*[3] or black sugar, was a generic term for sugars made by boiling to a point where they crystallised and crystals were retained in a heavy syrup. Like *guḍa*, the modern term for *gur* in India, it varied in colour from a light yellow through red to black depending on the type of clarification applied.

[h] Chinese artisans made this sugar when they intended to drain, clay or wash the sugar, but it has no special name. Large grain was desirable for draining, and especially for claying where water washes away some of the grain.

[i] This type of sugar was very popular across Asia. It was a soft grain sugar with small, almost microscopic grains that were surrounded by a layer of syrup. It was quite 'dry', and melted in the mouth when eaten.

[j] The term muscovado was derived from Spanish, but explanations varied. Muscovado sugars were made almost exclusively in the English colonies of the West Indies, and denoted sugars that have the molasses drained off them in a hog's head through holes in the side, see Deerr (1), p. 109.

sugar]. If it crystallises (*tuan*[1] [lit. breaks]) it is ready (*shu*[2]) and forms *sha-thang*. If it does not crystallise it is still not ready and is boiled again.

When making *sha-ko-ling* [i.e. *shih-mi*] return [the *sha-thang*] to the pan and after boiling it put it into a bamboo steaming bucket with seven holes in the base (*chu tsêng*[3]),[a] and the molasses (*shui*[4] [lit. water]) drains down into a receiving earthenware jar (*wêng*[5]) placed below. Keep the door [of the room in which the sugar in the bamboo steaming buckets are stored] closed for a full fifteen days [before] opening and removing. After the *sha-ko-ling* has been drained out in the bamboo steaming bucket bring it together by hand and remove [any remaining molasses] by shaking [*san chhu*[6] lit. scatter, to remove]. [This is] called *sha-ko-ling*. The molasses (*shui*) that has been drained off is made into wine (*chiu*[7]).[b]

Stalks of sugarcane like panicum (*mei*[8]) in Sha-Chou[9] and Kao-Chhang[10] do not set seed (*wu tzu*[11])[c] [so] take a stalk one *chhih* [31 cm in length] cut and bury it on ploughed ridges (*li lung*[12]) and it will grow. When planting sugarcane use the twelfth lunar month [*mu*[13]].[d]

The technology for manufacturing the Indian sugars *khaṇḍa* and *śarkarā* have long remained a mystery (see Table 16). On the basis of the information provided in this text, we are able to identify the manufacturing technology of *khaṇḍa* (*sha-thang* in Chinese). Artisans made it by beating a supersaturated

Footnotes to page 373 (*cont.*)

as evidence that *chārikam* has not been translated correctly as ashes in the past by Western scholars. If fine ashes were added, perhaps they acted as foci for crystallisation.

[a] According to the *WCNS* of +1313 pp. 304–6 a *tsêng*[14] is a bucket for steaming which is placed on top of a boiling pan. This bucket is broader at the top than the bottom, and has seven holes in its base, which are covered on the inside with a bamboo frame. In this case the bucket is being used to drain the syrup from the sugar. For illustrations of a bronze *tsêng*[14], an apparatus of two separate vessels with grating between them see Vol. 5, pt 4, p. 29.

[b] This is the first extant reference to making sugarcane wine in China.

[c] Chi ((*1*), pp. 135–6) read the character *mei*[8] as *mi*[8] taking it in the sense of rice congee, and therefore interpreted this line to mean, sugarcane stalks like the rice congee (*mi*[8]) in Sha-Chou and Kao-Chang do not bear grain food. I offer a different interpretation because *mei*[8] refers to a type of millet, panicum, see Vol. 6 pt 2, p. 440. *Wu tzu*[11], literally meaning without children, refers to the inability of sugarcane to flower in high altitudes and latitudes.

[d] The original text has the character *mu*[13], meaning eye. Chi (*1*), pp. 125, 134 takes *mu* to be a mistake for *yüeh*[15], month, hence this translation.

[1] 斷 [2] 熟 [3] 竹甑 [4] 水 [5] 甕
[6] 散去 [7] 酒 [8] 糜 [9] 沙州 [10] 高昌
[11] 無子 [12] 犁壠 [13] 目 [14] 甑 [15] 月

Notes to Table 16 (*cont.*)

[k] The English word sugar derived from the Sanskrit *śarkarā* through the Persian *schakar*, see Baxa & Bruhns (1), p. 325. Such a generic word was probably applied to a range of sugars.

[l] Additional terms were *ping-thang*[12]. From the +17th century we find terms such as honey pieces (*mi-phiên*[13]) and cows hide sugar (*niu-phi-thang*[14]).

[m] *Satyāpīr* was a Hindu deity derived from the Hindu saint Nārāyana, see Ray, J. C. (1) p. 445 fn. *Satya* (Sanskrit) means true and *pīr* a saint in Urdu (Persian), see Walker, B. (1), vol. 2, p. 124.

[1] 蔗漿 [2] 石蜜 [3] 黑糖 [4] 沙糖 [5] 糖水
[6] 糖霜 [7] 招魂 [8] 甘蔗之漿 [9] 甘蔗漿 [10] 黑石蜜漿
[11] 半蜜 [12] 冰糖 [13] 蜜片 [14] 牛皮糖



Fig. 104. *Sha-thang*[1] is still made at Muroto, Kochi prefecture, Japan, in the 20th century as a speciality sugar under the name of *kurozatō*[2]. There the sugar is not beaten to dryness, but poured into moulds while the massecuite is still fluid. When dry the bricks are removed from the moulds. These soft-grained sugars melt in the mouth and are highly appreciated as traditional products; orig. photo Christian Daniels, December, 1981.

sugar syrup in a trough with a paddle, which caused the growth of a very fine grained sugar, admirably described as *sha-thang*[1] or sand sugar.[a] The heat of crystallisation drives off the remaining water, and a reasonably dry fine-grained sugar resulted within an hour.[b] This method survived until the 19th century in

[a] *Khaṇḍa* is equally appropriate in Sanskrit as the word has the connotation of striking, beating and broken, which is descriptive of the process, see Monier-Williams (1), p. 336. The derivation of the term *sha-thang* remains unclear, but in the *Chü Lu*, *hsia*, ch. 2a of +1178 it is written that the people of Wên-Chou[3] in Chekiang invariably called things small, sweet and beautiful *sha*[4] (sand), and listed *sha-kua*[5], *sha-mi*[6] and *sha-thang*[1] as special dialect words.

[b] The heat of crystallisation is heat given up by the syrup on crystallisation, and amounts to about 13 CHU per lb. This is an example of the Le Chatelier principle on the change of state, see Lyle (1) pp. 469, 595.

[1] 沙糖 [2] 黑砂糖 [3] 溫州 [4] 沙 [5] 沙瓜
[6] 沙蜜

India, Japan (Fig. 104) and China.[a] In the Visayas, the Philippines, it found application on plantations producing 400 tons per year.[b] A late 19th-century observer reported on the simplicity of the procedure at Iloilo on Panay Island:[c]

> The juice is boiled until it arrives at a certain density, only to be judged by an experienced boiler, and it is then emptied into wooden troughs or trays in thin layers and beaten until it assumes a yellow colour, and becomes an amorphous sugar, known as 'Superior de Iloilo'. It is put in bags for sale immediately, and is ready for exportation without any preparation. It does not drip molasses, and its loss in weight is insignificant.

The second type of sugar, *śarkarā* (*shih-mi* in Chinese), was made by dissolving *sha-thang* in water, and boiling. The syrup was then crystallised slowly by gentle stirring to produce a large-grained massecuite. Next the massecuite was placed in a utensil with a hole in the bottom. The solid sugar, *śarkarā*, remained in the utensil while the molasses passed below where it was collected. Draining first appeared in the P 3303 manuscript in relation to *śarkarā*. The name *śarkarā* dated back to the *Arthaśātra* (mean date −100) and the *Caraka* (+1st to +2nd century) indicating the possibility of some type of draining technology at that time. The technology involved may not be drainage from a bucket or cone, as 19th-century India boasted three drainage techniques which may be ancient. The first comprised the pouring of massecuite into a hole in the ground lined with cloth, which allowed the syrup to soak through into the ground.[d] In the second, artisans put the massecuite into bags, on top of which they placed weights to force the syrup to ooze out through the bag wall.[e] The third involved pouring massecuite into a tank with a bottom of bamboo slats covered with cloth and syrup drained through.[f]

When this technology reached China during the mid +7th century, I suggest, on the basis of the P 3303 manuscript, that a bamboo steaming bucket and earthenware jar were adopted for draining. Probably sometime after +1000, the bamboo steaming bucket or its equivalent in other countries, was replaced by a clay cone for draining massecuite, and as cones could be mass produced, coning became the standard method of drainage. In coning, massecuite was poured into a cone, a jar made of pottery wide at the top but pointed at the bottom, which was supported by another jar below (see Figs. 105 and 106). The molasses in the massecuite flowed down and out through the bottom hole and into the jar below. This innovation found favour because after all the molasses had been drained, the cone could be inverted, and sugar would come out whole in the shape of the cone, often known as loaves.[g] The sugar at the top of

[a] Watt (1), vol. 6, pt 2, p. 281 for India and Lock, Wigner & Harland (1), p. 622 for China.
[b] United States Consul (1), p. 76. Locsin ((1), p. 44) quoted a source as reporting that plantations produced about 400 tons per year.
[c] United States Consul (1), p. 76.
[d] Watt (1), vol. 6, pt 2, pp. 304, 306.
[e] Deerr (1), p. 449.
[f] Watt (1), vol. 6, pt 2, p. 284.
[g] In the West sugar loaves were hardened by drying in an oven, not baked like bread as the term sugar loaf would suggest.

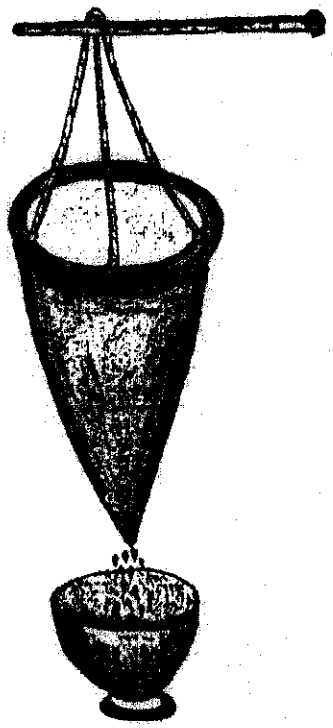


Fig. 105. An alchemical filtering utensil, as illustrated in a +15th-century manuscript, held in Padua University Library. This illustration poses the question as to whether sugar-draining cones were not an adaptation from alchemy; from Abe Kinya (1), No. 20, E 119.

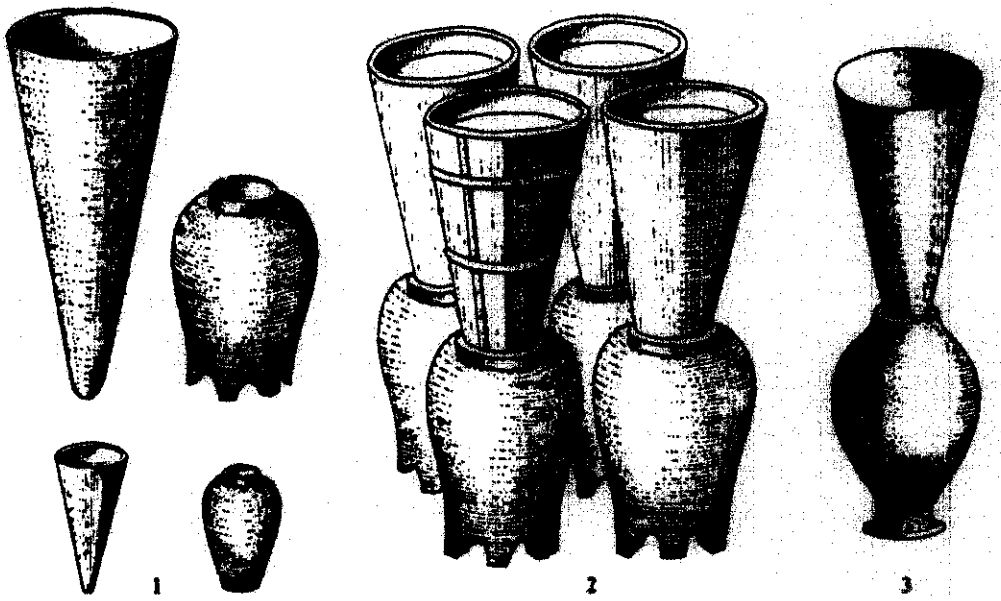


Fig. 106. +18th-century representations of sugar-draining cones and receiving jars in Europe and the West Indies. Nos. 1 and 2 after Diderot and no. 3 after Labat through Brooks (1), p. 9.

the cone turned the whitest and that at the bottom, or narrow end, the darkest. The loaf could be sold by merchants, either whole, or readily broken up into grades.

Śarkarā appeared in Amarshiṇha's *Nāmalinganuśāsana*, usually called the *Amarakośa* of c. +500, and was associated with clay pot, or jar production.[a] Deerr (1) followed von Lippmann in attributing the invention of the draining cone to the Nestorian Christians of Jundi-Shâpûr, although he conceded that the Indians may have drained sugar by other means before this time.[b] The first known literary reference to cones appeared in the *Kitāb al-falāḥa* of the Hispano-Islamic agronomist Ibn al-'Awwām (second half of +12th century) who cited an earlier writer Abu 'l khayr al-Ishbīlī c. +1100.[c] Cone shaped drainers have been discovered by archaeologists in the Mediterranean. Thousands have been recovered from Cyprus, probably dating from the +15th or +16th centuries. Archaeologists have distinguished three main types of moulds with volumes of approximately one, four and eight litres.[d] From this we can assume a Mediterranean or Middle Eastern origin for the cone, but we must remember that the P 3303 manuscript discussed earlier described a draining procedure for China in the pre +1000 period.[e]

The apparatus for draining the sugar was a *tsêng*[1], which the *Nung Shu* of +1313 described as a steaming bucket placed on top of a boiling pan. This bucket was broader at the top than the bottom, and had seven holes in its base, which were covered on the inside with a bamboo frame (see Fig. 107). Such buckets must have been adopted to drain the syrup from the sugar.[f]

In the +1503 gazetteer for Hsing-Hua prefecture in Fukien the apparatus for draining the sugar was called the *hun*[2] and *wo*[3]. This source remarked: 'Use two different utensils which ride one on top of the other. The top one is called a *hun*[2] [lit. pigsty, toilet for humans] and the bottom one is called *wo*[3] [lit. a cave or den]. The base of the *hun*[2] is pointed with a hole [in the bottom]. The *wo*[3] is empty inside with a solid base';[g] these two objects constituted a cone and receiving jar (Figs. 108 and 109). The Hui-An county gazetteer of +1530 described similar utensils: 'Use an earthenware vessel (*wêng chhi*[4]) that is broad at the top and pointed at the bottom like the leaking wine cups (*lou chih*[5]) in the drinking

[a] Sarde Sai & Padhyte ((1), p. 134) inferred that *śarkarā* was clayed sugar, but clay certainly referred to the jar and not the process.

[b] Deerr (1), p. 450.

[c] Deerr (1), pp. 80–1. See Sarton (1), vol. 2, pt 1, p. 424 for a summary of Ibn al-'Awwām's agricultural work the *Kitāb al-falāḥa*. For Abu 'l khayr al-Ishbīlī. Deerr (1) gave Abu-el Jair and von Lippmann ((4), p. 242) wrote Abu'l Chair, but we follow Lewis, Pellat & Schacht (1), vol. 2, p. 901.

[d] von Wartburg (1), pp. 309–11.

[e] Chi (*1*), pp. 124–5. See the translation given on pp. 373–5, paragraph beginning, 'When making *sha-koling* . . .'.

[f] *WCNS*, pp. 304–6. For illustrations of bronze *tsêng*, an apparatus of two separate vessels with grating between them, see Vol. 5, pt 4, p. 29.

[g] +1503 *Hsing-Hua FC*, ch. 12, pp. 11a–11b.

[1] 甑 [2] 厠 [3] 窩 [4] 甕器 [5] 漏卮

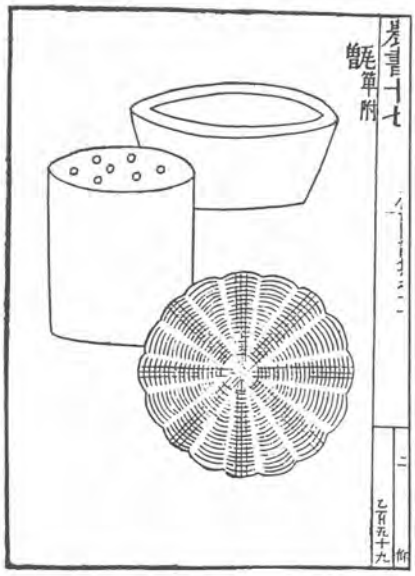


Fig. 107. An illustration of a *tsêng*[1], or bamboo steaming bucket, from the *Nung Shu* of +1313 *nung-chhi thu-chi*, ch. 11, p. 2b. Notice that holes for draining are clearly visible.



Fig. 108. Clayed sugar draining in large earthenware jars (*pilones*) with a holding capacity of about 130 to 180 lbs. These jars were about 2 feet high and the mouths were 1.5 feet in diameter. The molasses drained into containers below. This scene shows large-scale production by Chinese manufacturers in the Philippines during the early 20th century; Hines (2), p. 300.

[1] 甑

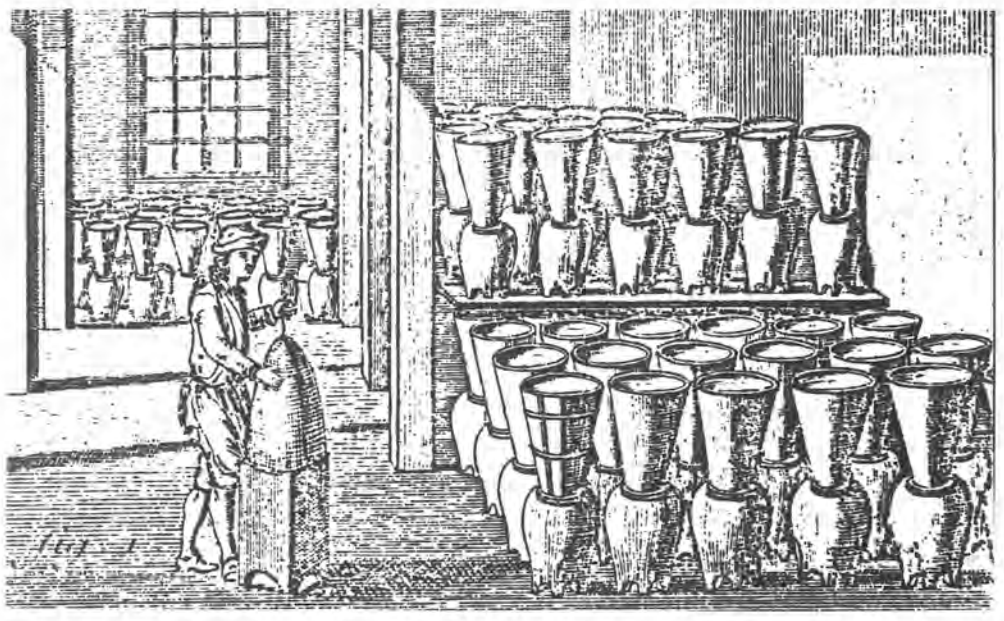


Fig. 109. The claying process for making white loaf sugar in the French colonies in the +18th century. The heavy massecuite was poured into cones, a layer of moist clay added and the syrup allowed to drain into the containers below. After two or three changes of clay the sugar loaves were removed. The sugar loaves were so white that they could be shipped to France for direct consumption; the *Encyclopédie* of Diderot through Gillispie (2), pl. 41, Sugar v.

houses of the present day. The hole at the pointed end is stuffed with grass, and a porcelain jar (*tzhu weng*[1]) is placed underneath to receive [the molasses that drips down].'[a] The *Min Shu* of +1631 gave the following account: 'The porcelain draining jar (*tshu lou*[2]) resembles a bowl (*mao khuei*[3]) with a hole in the base from which the molasses (*shui*[4]) comes out.'[b] These types of drainers were the predecessors of the later *wa liu*[5] and *wa lou*[6]. In some of the sugar-producing districts opened up for Chinese settlement after the +17th century sugar drainers had to be imported from older districts. In Chu-Lo county[7], southern Taiwan, the clay proved so poor for making sugar drainers, that they all had to be imported from the mainland along with boiling pans (*fu chheng*[8]).[c]

The +1503 gazetteer for Hsing-Hua prefecture furnished the first detailed description of claying in China:[d]

White sugar (*pai-thang*) is made in the first lunar month of each year by refining *sha-thang*. Select good and dry *sha-thang*, put it into a large cauldron (*ta fu*[9]) and boil (*phêng*

[a] +1530 *Hui-An HC*, ch. 5, pp. 20a–20b.
[b] +1631 *MS*, ch. 150, p. 33b.
[c] +1717 *Chu-Lo HC*, p. 296.
[d] +1503 *Hsing-Hua FC*, ch. 12, pp. 11a–11b.

[1] 盛甕 [2] 盛瀉 [3] 帽盌 [4] 水 [5] 瓦溜
[6] 瓦瀉 or 瓦漏 [7] 諸羅縣 [8] 釜鐺 [9] 大釜

lien[1]) [it]. The albumen and yolk of a duck's egg are mixed into the boiling sugar to get the impurities to float to the surface. Use a skimmer made of iron to scoop [the impurities from the surface of the boiling syrup and make it] clean. Watch the fire and wait until [the syrup has been boiled] sufficiently [before ladling it into the cones].

Use two different utensils which ride one on top of the other. The top one is called a *hun* [lit. pigsty, toilet for humans] and the bottom one is called *wo* [lit. a cave or den]. The base of the *hun* is pointed with a hole [in the bottom]. The *wo* is empty inside with a solid base.

Fill the hole [in the base of the *hun*] with grass, put the boiled sugar syrup (*thang chiang*[2]) into the *hun* and stir it while it is still hot. The sugar will gradually crystallise (*ning ting*[3]) after cooling.

By removing the grass bung the syrup drained into the *wo* below.

The *Thien Kung Khai Wu* of +1637 provided the first account of what we know as a European style cone in China:[a]

Next, an earthenware cone (*wa liu*[4]) (potters can be taught to make them), is placed over a large jar [see Fig. 110]. The cone is wide at the top and pointed at the bottom. The small hole at the base of the cone is plugged with straw. The black massecuite (*hei sha*[5]) is transferred from the tubs into the cone. When the black massecuite is set (*chieh ting*[6]), the straw is removed from the hole, and yellow clay water is used to wash it down (*yung huang ni shui lin hsia*[7]).

I shall now review the origin of another major sugar in China, sugar candy.

Transfer of sugar-candy-making technology

There is yet another case of technological transfer attributed to the Thang. The great Sung monograph on sugar candy, the *Thang Shuang Phu* of c. +1154, related that a Buddhist monk called Tsou[8] conveyed the art of making sugar candy to Umbrella Mountain in Sui-Ning[9], Ssu-Chhuan province during the Ta-Li[10] reign period (+766 to +779) of the Thang dynasty. The circumstances of the transmission are of extreme interest to the above discussion, and I cite the relevant passage in full:[b]

Formerly during the Ta-Li reign period [+766 to +779] of the Thang, a Buddhist monk called Tsou, whose origin remains unknown, ascended Umbrella Mountain (*San-Shan*[11]) astride a white donkey and built a grass hut [there] for his residence. [When he] required salt, rice, firewood, or vegetables he would write [his needs] on paper, tie it onto the donkey [together with] the money, and send it to the market. The people in the district knew that it was for Tsou, took the right amount of money, hung the articles he wanted on the saddle and sent the donkey back. One day the donkey offended a certain Mr Huang[12], who lived below the mountain, [by eating] his young sugarcane. Huang requested compensation from Tsou, who [in reply] said, 'You do not yet know

[a] *TKKW*, pp. 169–70.
[b] *TSP*, pp. 1a–1b; Liu & Liu (*1*), pp. 11–12.

[1] 烹煉 [2] 糖漿 [3] 凝定 [4] 瓦溜 [5] 黑沙
[6] 結定 [7] 用黃泥水淋下 [8] 鄒 [9] 遂寧 [10] 大曆
[11] 徽山 [12] 黃氏



Fig. 110. An illustration of the Chinese claying procedure from the original +1637 edition of the *Thien Kung Khai Wu*, ch. 6, p. 78b, held by the Seikadō Bunko, Tokyo. The operator is applying moist clay to massecuite sugar (*hei-thang*) in a cone (*wa-liu*) placed on top of a larger jar for collecting the drained molasses. Behind the operator are two containers labelled yellow clay water (*huang ni shui*). Tai ((*1*), p. 114) and Matsuura Toyotoshi ((*1*), pp. 233–4), argued that yellow clay water was water and not clay, and therefore would wash away the sugar crystals as well as the molasses, and for this reason they insisted that the claying method as depicted in this *TKKW* illustration was not very effective, though they did recognise the effectiveness of the use of clay as described in other Chinese sources. To understand this process one must consider the action of claying in which water percolated from the clay through the massecuite washing off the molasses surrounding the crystals, leaving white sugar. There may be minor adsorption action of colouring matter onto clay particles suspended in the water. This leads us to conclude that the yellow clay water of the *Thien Kung Khai Wu* referred to a mixture of clay and water, or more precisely a moist clay. Here the operator was adding moist clay, and not pure water, to the cone in the same fashion as all the other references.

how to bury cane sugar (*yin chê thang*[1])[a] to make sugar candy. The profit must be ten times [greater than that from other sugars]. As compensation I will impart [the method of making sugar candy] to you.'

[Huang] tried the method and believed him in the end. The sugar-candy-producing

[a] The character *yin*[2] literally means to bury. Liu & Liu ((*1*), p. 11) claimed that *yin*[2] means putting in jars to steam and boil, but I suggest that it refers to storing of boiled syrup in jars and waiting for the cold to induce crystallisation, for this was essentially the secret of making sugar candy, and dictionaries do not give the meaning of steaming and boiling.

[1] 窨蔗糖 [2] 窨

households close to the mountain and those facing Umbrella Mountain all willingly [followed Monk Tsou's instructions], otherwise they would never have been able to make [sugar candy].

Tsou in his last years left [Umbrella Mountain] and went away to the north. The disciples who chased after him, caught up with him while passing through Chhüan county[1] [on the border of Chhêng-Tu[2] prefecture] at Spiritual Vulture Peak [*Gṛdhra-kūta*] shrine (*Ling Chiu Shan Khan*[3]). But all they saw was a stone image of *Mañjuśrī* (*Wên Shu*[4]). Only then did the followers realise that [Tsou] was a boddhisattva in his *nirmāṇa-kāya* body, and that the white donkey was the lion [*Mañjuśrī* rides]

The place where Tsou built his grass hut is now the Laṇkā monastery (*Leng Yen Yüan*[5]). Sugar-candy-producing households have drawn a picture of Tsou [there] and worship it as *Mañjuśrī*.

Monk Tsou as compensation for the misdemeanours of his donkey taught this technology to neighbouring households, and consequently the area surrounding Umbrella Mountain turned into one of the most famous *thang-shuang* production centres during the Sung dynasty.[a] Leaving aside the folklore, this story was significant because of the association of Buddhist monks with the introduction of sugar technology, even over a hundred years after the so-called technological mission of +647 to +648. It also highlights the point that the spread of sugar technology during the Thang did not rely on unified action on the part of the State, but was probably carried out on an *ad hoc* basis by interest groups or individuals in society, in this case the Buddhist *saṅgha* over a long period of time.

The sugar candy we have been discussing was a large-grained sugar with crystals ranging from approximately 2 to 40 mm. It appeared initially in India under the name *sitopalā* in the *Suśruta Saṃhitā* and Bower manuscript of the +4th century.[b] It may have been considerably older and derived from a technique still practised in 19th-century India, in which artisans crystallised sugar out slowly into large crystal masses in cloth-lined holes dug in the ground.[c] It is thought that the statement by Megasthenes, ambassador of Seleucus Nicator at the court of Chandra Gupta Maurya at c. −300: 'stones are dug up which are the colour of frankincense and are sweeter than figs and honey' may refer to this technique,[d] and hence a crude form of candy. Alternatively sugar candy could have been first produced accidentally as, under the conditions of a north Indian winter, any concentrated syrup exposed to the elements would gradually become supersaturated and grow large crystals.

As noted earlier the Chinese called sugar candy *thang-shuang* or *ping-thang*. It is

[a] *TSP*, pp. 1a–1b.

[b] Monier-Williams (1), p. 1214; Deerr (1), p. 48. For dating see Winter (1), pp. 149–50. In the modern world sugar candy is known as 'kandis' in India, 'coffee crystals' in England, 'diamonts' in Holland, 'rock candy' in the USA.

[c] Watt (1), vol. 6, pt 2, pp. 305, 307.

[d] See Deerr (1), pp. 63–4.

[1] 泉縣 [2] 成都 [3] 靈鷲山龕 [4] 文殊 [5] 楞嚴院

difficult to determine its advent there, and we must accept provisionally the traditional dating of +766 to +779 given in the *Thang Shuang Phu* of c. +1154 discussed above. The first literary reference to sugar candy appeared in a poem of c. +1090, by the celebrated Sung poet and official Su Tung-Pho[1] (+1036 to +1101):[a]

> The river Fu[2] and the Chung Lêng[3] [stream]
> Both a mass of water
> Ice plates presenting amber
> How can they be as beautiful as sugar candy?

For the subsequent century we are fortunate in having the *Thang Shuang Phu*, from which we have already quoted extensively. The section on making sugar candy provided a great amount of detail:[b]

Once again take the stored syrup [out of the earthenware jars] and boil it to a point where it is ninety per cent finished (*chiu fen shu*[4]). [At this point] wait for it to turn into the consistency (*chhou*[5]) of hard malt sugar (*hsing*[6]), then insert slits of bamboo into the earthenware jar, and only then pour [the syrup] into it and cover with a sieve. This is the way of making sugar candy. (If one hundred per cent finished it will become too thick and form [the lowest grade of crystallised sugar] sand bottom (*sha chiao*[7]). *Sha*[8] is read *sha*[9].)[c]

The quality and colour of sugar candy in a single jar naturally differs. The best is [a conglomerate of crystal] piled up like miniature artificial mountains, next followed by clustered branch, next glossy jar and next small grain lump (*hsiao kho khuai*[10]). The lowest grade is sandy bottom (*sha chiao*[7]). Purple is regarded as the best [colour], next deep amber followed by light yellow. Pale white is the least liked.

Irrespective of the size [of the crystals, one of] the most prized [sugars] is commonly called horse's teeth sugar candy (*ma chhi shuang*[11])[d] [the crystals of which are] grown closely together on the wall [of the jar]. Any sandy bottom covering the surface is scraped off. Furthermore, there are big lumps, some ten *chin*[12] [6 kilos] and others twenty *chin* [12 kilos]. The most unusual ones attain thirty *chin* [18 kilos]. The sandy bottom lying in the middle [of the jar at the bottom] is called abandoned (*shê*[13]).

Again the *Thang Shuang Phu* was quite specific on the role played by cold weather in the production of sugar candy in Ssu-Chhuan:[e]

[a] *Chu Tung-Pho Hsien Shêng Shih*, ch. 21, pp. 38b–39a. The name of the poem is *Sung Chin-Shan Hsiang Sêng Kui Shu Khai Thang*[14] and the *TSP*, p. 2a recorded that it was composed during the Yüan-Yu reign period (+1086 to +1093).

[b] *TSP*, pp. 4b–5a; Liu & Liu (*1*), pp. 15–16.

[c] One hundred per cent obviously refers to the striking point when making *sha-thang*. The ninety per cent for *thang-shuang* is probably just on saturation point. The syrup became supersaturated as winter temperatures became lower.

[d] The same terminology horse's teeth nitre (*ma ya hsiao*[15]) was employed for saltpetre crystals in the *TKKW*, p. 397; also see Vol. 5, pt 4, p. 193.

[e] *TSP*, pp. 4b–5a; Liu & Liu (*1*), pp. 15–16. The use of cold weather for concentrating alcohol is discussed in Vol. 5, pt 4, pp. 151–4.

[1] 蘇東坡 [2] 浯江 [3] 中泠 [4] 九分熟 [5] 稠
[6] 餳 [7] 沙餳 [8] 沙 [9] 嗄 [10] 小顆塊
[11] 馬齒霜 [12] 斤 [13] 舍 [14] 送金山鄉僧歸蜀開堂
[15] 馬牙消

After the syrup (*thang shui*[1]) has been in the jar for two days, it resembles the pattern of congee. By taking some on the finger and feeling it you will see that it is similar to small crystal sand (*hsi sha*[2]). After the fifteenth day of the lunar new year [i.e. after about two months in the jars] small lumps form and [sugar crystals] also conglomerate on the ends of the bamboo slits like ears of millet. [The crystals] gradually grow as large as a bean or even a knuckle. The enormous ones are as large as artificial mountains. This growth process is colloquially known as fruiting (*sui kuo tsu chieh shih*[3]).

Since the crystals do not grow any larger after the fifth lunar month when the cycle of crystal formation and growth has completed itself (*chhun shêng hsia chang chih chhi i pei*[4]), drain the jars (if not drained before the beginning of summer, they will turn to syrup. Minor households hurriedly try to drain beforehand in the fourth lunar month). Molasses (*thang shui*[5]) still remains there amongst the sugar candy that has formed, [so the jars have to be drained]. The jar is drained by scooping out the molasses with a ladle, removing the sugar candy and draining it dry.

The technology was apparently quite simple; boiled sugarcane syrup was poured into a jar and left to slowly crystallise over the winter. However, it is obvious that the correct point to finish boiling was quite critical and required considerable expertise. The *Thang Shuang Phu* suggested that small crystals should form in the syrup after two days indicating mild supersaturation. Crystallisation occurred on bamboo slits, which were inserted into the jar to act as resting places for crystal foci to form.[a] The crystals had to be harvested by early summer otherwise they redissolved in the hot weather. This method took advantage of the cold winters, and did not require great attention to be paid to the purity of the syrup. But abnormal high winter temperatures and neglect of the correct boiling point of the syrup caused great variability in the degree of crystallisation. The *Thang Shuang Phu* specifically stated how producers coped with such failures:[b]

It takes about one and a half years from cultivating the field to draining the earthenware jar. On the day the jars are opened, sometimes there is only a slight amount of sugar candy, other times several ten *chin* [c. 12 kilos] and on other occasions close to a hundred *chin* [c. 60 kilos]. Some people suddenly become wealthy, [and for that reason] it is a custom in the villages to divine whether the family is on the road to prosperity or decline [by the amount of sugar candy in the jars when opened].

If no sugar candy crystallises at all (*shuang chhüan pu chieh*[6]) [sugar-candy makers] can still obtain a good price on the original cost, and avoid large losses, by selling the molasses (*thang shui*), or by boiling it into *sha-thang* themselves. When molasses (*shui*) constitutes about half of the sugar obtained, [it] can also be sold or personally reboiled into *sha thang*. Nevertheless, when the whole jar turns into sandy bottom (*sha chiao chê*[7])[c]

[a] Artisans employed the same methods in saltpetre production at a later date. Maize stalks were used for providing sites for nuclei in south-west Ho-Pei in the 20th century, see Vol. 5, pt 4, p. 192.

[b] *TSP*, p. 5b: Liu & Liu (*1*), p. 17.

[c] Sandy bottom or *sha chiao*[8] has the smallest crystals and is therefore the lowest grade of sugar in the jar, see *TSP*, p. 5a.

[1] 糖水　[2] 細沙　[3] 隨果子結實　[4] 春生夏長之氣已備
[5] 糖水　[6] 霜全不結　[7] 沙脚者　[8] 沙腳

[keep the best ten per cent, add water to dissolve ninety per cent [and reboil to make *sha-thang*].

During the spring first drain the earthenware jars (*li wêng*[1]), and dry [the sugar candy] in the sun. If the operation is a little late, then [the sugar candy] will turn to syrup (*shui*) [because of summer high temperatures].

In case of crystallisation failure the syrup and low-grade crystal sugars had to be reboiled to make *sha-thang* or sold as molasses. Of course this incurred great monetary loss on the producer as *sha-thang* and molasses did not fetch as high a price as rare and exotic sugar candy. Sugar candy was also made in sub-tropical Fukien and Kuang-Tung, where the process required stricter control.

The method adopted in these places depended on slowly increasing saturation with natural evaporation of water from syrup. This demanded more precise control of saturation with higher quality syrup, and was consequently more applicable to the sub-tropical south where ripened sugarcane yields higher purity juice. The optimum condition for growing larger crystals is a slightly supersaturated syrup (1.01–1.02), and a prolonged growing time, extending to one to two weeks or more, in a condition of minimum disturbance. As far as I know no coherent description of the process existed before modern times, probably because observers did not know what to look for, and operators imperfectly understood the basic procedures. There appear to have been two procedures. First, artisans allowed a slightly unsaturated syrup to concentrate gradually by natural evaporation of water over a two-week period with bamboo slips for nuclei.[a] The correct point has been recorded as when a small sample hardens upon being put into cold water.[b] This method included uncontrollable elements, such as rates of evaporation and considerable drops in temperature that can occur at night in sub-tropical winters. Both of these elements may have led to concentration occurring too rapidly and premature grain in the syrup. The premature grain settled to the bottom of the jar to form sandy bottom, and thus diverted growth away from the bamboo nuclei. The second method practised in the 19th century, and possibly earlier, obviated this by keeping the jars in a heated warehouse preferably at a constant temperature of roughly 50°C.[c]

The *Thien Kung Khai Wu* of +1637 elaborated methods in a more temperate climate:[d]

To make ice sugar (*ping-thang*[2]) ocean sugar (*yang-tang*[3]) is dissolved and boiled, clarified (*chhêng*[4]) with egg white and the scum that floats [to the surface of the boiling syrup] is removed. When the temperature is judged [to be correct] throw strips of fresh green

[a] Yamane ((1), pp. 504–5) described the process in modern China.
[b] See Lock, Wigner & Harland (1), p. 621 on sugar-candy-making in 19th-century China.
[c] See Yamane (1), pp. 503–5 for methods in modern Asia.
[d] *TKKW*, p. 170.

[1] 瓶甕 [2] 冰糖 [3] 洋糖 [4] 澄

bamboo cut into pieces measuring one *tshun*[1] [3.2 cm] into the syrup. It will naturally form ice lumps (*ping khuai*[2]) after being left for one night.

The quality of the sugar used to make [figures of] lions, elephants, people and other things [can be freely chosen] by people. There are five grades of white sugar (*pai-thang*[3]); the best is rock mountain (*shih shan*[4]), followed by clustered branch (*thuan chih*[5]), next glossy jar (*weng chien*[6]), small grain (*hsiao kho*[7]). Sandy bottom (*sha chiao*[8]) is the lowest [grade].

This passage contains several obvious errors. The older methods of four to five months for crystallisation north of the ranges sound excessive, but one night was surely an exaggeration. Walkhoff suggested eight to ten days for forming reasonably sized crystals, and Yamane recorded ten to fourteen days as an appropriate time period.[a] In addition, the author, Sung Ying-Hsing, made another mistake in the last part of this text; the white sugar must refer to sugar candy because the five grades are all types of sugar candy, not ordinary clayed sugar. As stated earlier the term *ping-thang*, or ice sugar, was synonymous with *thang-shuang* and referred to sugar candy.[b]

The period between the +12th and +17th centuries witnessed considerable development in sugar-candy manufacture. As techniques progressed, sugar candy ceased to be made directly from juice, but was manufactured from redissolved sugar of the highest grade, which underwent further clarification with eggs before being crystallised into sugar candy.[c] Artisans aimed to obtain as high a quality of feedstock as possible to speed up the crystallisation process, and make it more predictable. This also allowed expansion of sugar candy production in sub-tropical places like Fukien and Kuang-Tung provinces.

The names for the five sugar candy grades given in the *Thien Kung Khai Wu* bear a close resemblance to those of the *Thang Shuang Phu*, nearly five centuries earlier. The only difference lies in the nomenclature of the best-grade sugar; the conglomerated crystals which 'piled up like miniature artificial mountains (*thui tieh ju chia shan chê*[9])' in the earlier work, became rock mountain sugar (*shih shan*[10]) in the later text of the +17th century. Both terms plainly referred to the same grade. This similarity of terms indicated that the shape of the final product had not changed, and that, though purer sugar was used as raw material for making sugar candy by the +17th century, the actual technique of placing boiled syrup in a jar and allowing it crystallise out slowly on bamboo slits remained essentially the same.

Sugar candy was graded for sale on the market according to the size and shape of the crystals; consumers attached greatest value to the larger and

[a] Walkhoff (1), p. 353 and Yamane (1), p. 504.

[b] *MS*, ch. 150, *shang*, p. 33a.

[c] See also from the contemporary *Min Shu* of +1631 and the *Wu Li Hsiao Shih* of +1664 below under reboiling.

[1] 寸 [2] 冰塊 [3] 白糖 [4] 石山 [5] 團枝
[6] 甕鬆 [7] 小顆 [8] 沙腳 [9] 堆疊如假山者 [10] 石山

stranger-shaped crystals. The size and appearance of the sugar crystals varied depending on where they formed within the jar. The two top grades had the biggest crystals which formed around the bamboo slits. The best grade crystals were 'as large as a miniature artificial mountain'. Second came clustered branches, which grow out from the bamboo slits like the branches of a tree. Third in line came the two types that grew on the walls of the jar; glossy jar and horse's teeth sugar. The fourth and fifth grades comprised small grain crystals, small grain lump and sandy bottom. By the +19th century the crystallisation jars were broken up into three or four pieces and bound on the outside with bamboo or rattan hoops.[a] This facilitated the recovery of the crystals formed on the side of the jars.

We have reviewed the methods of manufacture of all the sugar products listed as basic; amorphous sugar (*shih-mi*), black sugar (*hei-thang*), beaten sugar (*sha-thang*) and sugar candy. These were the range of products available in China until c. +1200. We are now in a position to identify the ancient Indian and Chinese sugars which are compared in Table 16.

(iii) *Claying*

Artisans superimposed an additional innovation upon draining technology sometime around +1200. They discovered that if they added a layer of moist clay to the top of the sugar draining in the cone, water percolated slowly from the clay giving a continuing washing action. Some scholars considered that colouring matter and other impurities were adsorbed onto clay particles suspended in the water,[b] but there has has been no experimental work conducted on this problem. This process improved the quality of the product known in the West as clayed sugar, and *pai-thang*[1] in China.

Von Lippmann has reviewed claying in some detail. He found the first mention of cones, and therefore the possibility of claying, in a Persian work the *Kitāb al-Mansūri* of al-Rāzī (d. +923 to +924).[c] References to claying are rare, and the next notice appeared in the *Nihāyāt al-Arab fi Funūn al-Adab* of al Nuwairī (+1279 to +1332).[d] In the West the claying process can only be documented

[a] Lock, Wigner & Harland (1), pp. 621–2.

[b] Sun & Sun (1), p. 132.

[c] von Lippmann (4), p. 172. The evidence for this was very tenuous, and the first definite source appeared in the *Kitāb al-falāha* of Ibn al 'Awwām as mentioned earlier.

[d] Deerr ((1), vol. 1, p. 91) rendered the German translation of Wiedemann as follows: 'The boiled juice, called *mahlab* (honey), is poured into moulds (*ablug*) of earthenware, which are narrow below and wide above. In the bottom of each mould are three holes, which are plugged with sugar-cane. These moulds are placed in the house of the pouring, in which there are long benches like mangers (*midwad*). Under these moulds are vessels (*gadus*) into which flows that which is separated in fine drops. This makes the syrup and dropped honey. Then the people serve the moulds with *dakaschib*, one after the other till the moulds are full.' He commented that Wiedemann could not understand what *dakaschib* meant. I suggest that it could have been a special type of clay.

[1] 白糖

as far back as observations in the Canaries in +1570 by Francisco Hernandez, the physician to Charles II of Spain, who was sent on a Royal mission to record the natural history of New Spain, though it must have been employed earlier.[a] He returned to Spain in +1577 and his manuscript was bound in sumptuous purple, and though placed in the Escorial library never reached the publisher in his life time.[b]

In China the first detailed account of claying occurred in the +1503 gazetteer for Hsing-Hua prefecture on the Fukien coast,[c] though its practice dated from considerably earlier times. 17th-century sources referred to the accidental discovery of the art of claying in China. The *Min Shu*[1] of +1631 related a story which dated back to the Yüan dynasty:[d]

In the beginning no one knew the method of claying (*fu thu fa*[2]). During Yüan times in Nan-An[3] [county in Chhüan-Chou prefecture[4] on the Fukien coast] a certain Huang Chang[5] built a house to boil sugar. A wall of the house suddenly collapsed falling on the edge of the [top] of the drainer (*lou*[6]). [The sugar at the top of the drainer] became exceptionally white in colour, and [Huang] thereupon obtained a generous amount of money for it. Afterwards [people] imitated this method.

Another story in the *Kuang Yang Tsa Chi*[7] of +1695 presented a +16th-century

[a] Hernandez (1), p. 110. Hernandez' observations may have been preceded by Thomas Nichols who published *A Pleasant Description of the Fortunate Islands called the Islands of Canaria; With Their Strange Fruits and Commodities* in +1583. This is included in Astley (1), vol. 1, see p. 536 for a description of claying. The date Nichols visited the Canaries remains uncertain, but he was possibly there from +1554 for a number of years, see Stephen & Lee (1), vol. 14, p. 455.

[b] After his death a Royal physician, Leonardo Recchi (Recho), made a summary which was published in Rome in +1628 as *Rerum Novae Hispaniae Thesaurus, Seu Plantarum Animalium, Mineralium Mexicanorum Historia*. In +1651 Prince Frederico Anglo Cesi, founder of the Academia dei Lincei published the first full text in a version in five parts and it is called *Rerum Medicarum Novae Hispaniae Thesaurus* ... in +1649 and +1651. It had annotations by Johann Sclerck, Johann Faber and Fabio Colonna. The sugar sections of this text were virtually the same, see Hernandez (1), pp. 109–12. Meanwhile in Mexico Francisco Ximenes used a copy left there by Hernandez to issue an abridged Spanish translation under the title *Quatro Libros de la Naturaleza y Virtudes de la Plantas y Animales* in +1615, see Ximenes (1), pp. 56–8 (for sugar section). According to Gillispie (1), vol. 6, pp. 309–10 the copy of Hernandez' work kept in Mexico was consulted by Agustin Farfán for his *Tratado Breve De Medicina* ... Von Lippmann and Deerr erroneously treated Ximenes as the author of the sugar section of this text. They remained ignorant of the fact that Hernandez really wrote the original, despite the fact that Ximenes accredited him with authorship on the title page of his book. As a result they miss the point that the first reference to claying in the West was not +1615 but +1570. The sugar section in the Spanish version of Ximenes was translated into Latin and published by Georg Margrav in *Historia Naturalis Brasiliae* of +1648, see Piso & Margrav (1), pp. 85–6. The original manuscript was destroyed in the great fire of the Escorial palace in +1671. However, the 'indefatigable Muñoz' detected another manuscript in the library of the Jesuit college at Madrid in Hernandez' own hand. It was published by the famous press of Ibbara in +1790 under the title, *Historia Plantarum Novae Hispaniae*, see Prescott (1), p. 82, fn. 31. Casimiro Gómez Ortega edited and published the *Historia Plantarum Novae Hispaniae* in three volumes, and the British Library possesses a copy catalogued under 454.b.1–3. A Spanish translation was published by the Universidad Nacional de Mexico in +1959. Hernandez' complete works have been published in four volumes as *Obras Completas* by the Universidad Nacional de Mexico, +1959–66. For an account of the life of Hernandez and his manuscripts see, von Hagen (1); Gillispie (1), vol. 6, pp. 309–10; Goodman (1).

[c] +1503 *Hsing-Hua FC*, ch. 12, pp. 11a–11b.

[d] *MS*, ch. 150, p. 33b.

[1] 閩書 [2] 覆土法 [3] 南安 [4] 泉州府 [5] 黃長
[6] 滷 [7] 廣陽雜記

origin, but there is no reason to regard it as valid. Available evidence confirms that the Chinese definitely practised claying by the early +15th century.[a]

The term *pai-thang* referred to a white clayed sugar[b] and the Imperial court designated it as an article of tribute in Fukien from the early Ming. The Hui-An county[1] gazetteer of +1530 wrote:[c]

At the beginning of the [Ming] dynasty there were few articles of tribute. Our county only had 350 *chin* [210 kilos] of white sugar (*pai thang*), 100 *chin* [60 kilos] of sugar candy (*thang shuang*) and 110 *chin* [65 kilos] of *sha li pieh*[2], which were all locally produced.

As shown earlier, white clayed sugar first appeared as an article of tribute (*shang kung*[3]) in Fukien during the Yung-Lo reign[4] period (+1403 to +1424). This is strong evidence for the Chinese having practised claying during the late 14th century if not earlier, otherwise Hui-An county would not have been able to make clayed sugar for presentation as tribute in the early years of the +15th century. Furthermore, the Chinese term, *pai-thang*, appeared in the *Tao I Chih Lüeh*[5], a +14th-century Chinese account of South-East and South Asian countries, by Wang Ta-Yüan[6] who travelled over the region in the period +1339 to +1344; the section on Periyapattinam (*Ta Pa Tan*[7]) in Tamilnadu, on the southern coast of India mentioned *pai-thang* as an article of trade.[d]

In all stories people noticed the appearance of lighter coloured sugar on contact with wet clay. The significant point about the Chinese story related in the

[a] *Kuang Yang Tsa Chi*, ch. 2, p. 66a related the remarks of a Fukienese scholar, Lin Chih-Fan[8], who obtained his *chin-shih*[9] degree during the Chhung-Chen[10] period (+1628 to +1644) of the Ming dynasty: 'Prior to the Chia-Ching[11] reign period [+1522 to +1566] the world was without white sugar (*pai-thang*). That which the Fukienese boiled was all black sugar (*hei-thang*). During the Chia-Ching period when clay from the roof tiles of a sugar boiling establishment (*thang chü*[12]) chanced to fall onto a draining cone (*lou tou*[13]), it was observed that the colour of the sugar at the top [of the cone] was as white as frost and snow, and its flavour sweeter and more delicious than usual. The middle [of the cone contained] yellow sugar (*huang-thang*[14]) and the bottom black sugar (*hei-thang*). Thinking this abnormal they took clay (*ni*[15]) and pressed it on top of the [black] sugar, and it never failed [to produce white sugar]. It was from this time onward that white sugar was first known to the world.' This was undoubtedly an inaccurate account for the +1503 *Hsing-Hua Fu Chih* ch. 12, p. 11b cited an unidentifiable earlier gazetteer, which recorded the art of making white clayed sugar being known in the third or fourth decades of the +15th century. The text reads: 'The gazetteer [of Hsing-Hua prefecture compiled by] Phêng[16], wrote: Formerly [white sugar] was produced in Chhüan-Chou [prefecture]. During the Chêng-Thung[17] reign period [+1436 to +1449] Chêng Li[18], a man from Phu [Thien[19] county in Hsing-Hua prefecture] learnt the method [of making white sugar], and made it himself for the first time [in Hsing-Hua prefecture].' The story recorded in the *Kuang Yang Tsa Chi* clearly has no basis in fact as a man from Hsing-Hua had already learnt the art of claying as early as the +1430s and +1440s. The Chinese evidently knew of claying long before the +16th century.

[b] The early references to *pai sha-thang*[20], such as occurred in the *Chiu Wu Tai Shih*, p. 1463 under an entry for +951, and those to *kan pai sha-thang*[21] in the *Thai Phing Huan Yü Chi*, ch. 100, p. 3b which mentioned it as an article of tribute from Fu Chou indicated a milk clarified sugar, and not a clayed sugar.

[c] +1530 *Hui An HC*, ch. 7, p. 6b.

[d] *Tao I Chih Lüeh*, p. 280 and Karashima (1), pp. 5–8 for identification of *Ta Pa Tan* with Periyapattinam.

[1] 惠安縣 [2] 沙哩咧 [3] 上供 [4] 永樂 [5] 島夷誌略
[6] 汪大淵 [7] 大八丹 [8] 林之蕃 [9] 進士 [10] 崇禎
[11] 嘉靖 [12] 糖局 [13] 漏斗 [14] 黃糖 [15] 泥
[16] 彭 [17] 正統 [18] 鄭立 [19] 莆田 [20] 白沙糖
[21] 乾白沙糖

Min Shu lay in the claim that claying was an indigenous innovation of the Yüan dynasty, a time when there was every possibility of a transfer of technique from Central Asia or the Middle East. The Sugar Bureau, the *Sha Thang Chü*,[1] was set up in +1276, the same year in which the Mongols pacified the Chiang-Nan region. According to the *Yüan Shih*, the Sugar Bureau managed the boiling and manufacture of *sha-thang*.[a] From a reference in the *Yüan Shih* to the stoppage of the yearly tribute of cane syrup (*chê-hsing*[2]) from Fukien in +1326 due to a famine, we can surmise that the Sugar Bureau reboiled cane syrup into *sha-thang*.[b] It is possible that Uighur merchants participated in the administration of the Sugar Bureau, and may have been responsible for introducing claying and better clarification techniques. Also all stories concerning Chinese origins for claying derived from the seaboard area of Fukien province, especially near Chhüan-Chou, the port which Arab traders frequently visited and resided in between the +10th and +13th centuries. This history of contact with the Islamic world leaves ample room for technological transfer.[c]

The +1503 gazetteer for Hsing-Hua prefecture in Fukien elaborated on claying in China.[d] The passage quoted on p. 382 continues as below.

Use two different utensils which ride one on top of the other. The top one is called a *hun*[3] [lit. pigsty, toilet for humans] and the bottom one is called *wo*[4] [lit. a cave or den]. The base of the *hun* is pointed with a hole [in the bottom]. The *wo* is empty inside with a solid base [see Figs. 108 and 109].

Fill the hole [in the base of the *hun*] with grass, put the boiled sugar syrup (*thang-chiang*[5]) into the *hun* and stir it while it is still hot. The sugar will gradually crystallise (*ning-ting*[6]) after cooling. Perform [the next operation] during the plum rains of the third lunar month [May–June]. Cover the sugar [on top of the *hun*] with red clay (*chhih ni*[7]). By changing the clay covering after approximately half a month all the molasses (*thang yu*[8]) [on the sugar] will be drawn off into the *wo* [below]. In the month of the small [approx. 7th July] and the big heat [approx. 23rd July] break the clay [sealing] and remove the sugar; that [remaining in the *hun*] near the top is completely white, while that close to the bottom is slightly black. Thereupon dry it in the sun and store it in a wooden bucket.

The interesting feature of this passage is that sugar at the right saturation point was poured into the cone, and stirred until it crystallised. This gave the crystals time to grow; large crystals were favoured for claying because they reduced the amount of sugar lost in the molasses.

[a] *Yüan Shih*, p. 2204. Tai ((1), pp. 35–6) remarked that the Sugar Bureau may have been modelled after the Sweetmeats Bureau (*mi-chien chü*) of the Southern Sung.

[b] *Yüan Shih*, p. 669.

[c] Karashima (1), pp. 15–20 demonstrated constant contact between south India and Fukien during the +13th and +14th centuries with China and Ma'bar exchanging envoys at least twelve times between +1283 to +1314.

[d] +1503 *Hsing-Hua FC*, ch. 12, pp. 11a–11b.

[1] 沙糖局 [2] 蔗餳 [3] 圂 [4] 窟 [5] 糖漿
[6] 凝定 [7] 赤泥 [8] 糖油

Stories of accidental discovery of claying also abound in the West. For instance, one tradition claimed that claying was first discovered in Brazil where 'a hen having her feet dirty, going over a pot of sugar by accident, it was found under her tread to be whiter than elsewhere'.[a] It is possible that there may have been a transmission of some aspects of claying technology from China to Brazil, as after +1660 the Brazilians employed cones of up to 128 lbs,[b] which resembled the cones illustrated in the *Thien Kung Khai Wu* of +1637, and the large *pilons* used by Chinese manufacturers in the Philippines (see Fig. 108). Large cones with capacity for holding from one picul (60 kilos) to 200 lbs were characteristic of Chinese sugar makers in Taiwan during the late 19th century.[c]

We shall now briefly consider the mechanics and action of claying. William Hughes, a horticultural writer who returned to England after visiting the West Indian islands and Florida in about +1652, wrote in his work, *The American Physician*, 'cover the tops of these boxes, or earthen vessels, with a temper'd white earth: and indeed there is great art in whitening and making of good sugar'.[d] Von Lippmann wondered whether claying did not evolve from the more ancient application of alumina and white earths for the clarification of commodities such as wine, fruit juice, rose water and other fluids.[e] In China the range of variation in the materials employed only extended to different types of clays and soils. Chinese texts referred to the addition of *pai-thu*[1] or white earth, yellow clay water (*huang ni shui*[2]), fine smooth yellow clay (*hsi hua huang-thu*[3]) and plain clay (*ni*[4]) during the +17th century,[f] but sources mentioned red clay (*chhih ni*[5]) for the late +15th century and the +16th century, and mud from the bottoms of canals in south Taiwan for the +19th century.[g] The Chinese do not seem to have used anything else but wet clay for this process, and the quality of the clay does not seem to have mattered. This reinforces the concept that the action of claying was washing and not the adsorption of impurities onto the clay particles. More than anything their choice was probably dictated by local availability of clay types.

In India, drainage probably appeared very early to make *śarkarā*, but the implement of drainage remains unknown. There is no evidence of claying at all, but during the 19th century observers found Indians applying moist succulent

[a] Hernandez (1), p. 110; Piso & Margrav (1), p. 86. This story was also noted in Sloane (1), p. 61. Von Lippmann ((4), p. 406), ascribed a date of +1550 to this finding, even though the original source he cited for this story, Ximenes (1), made no mention of such a date. We now know that Hernandez, the source of Ximenes (1), observed claying in the Canary Islands in +1570. The quotation here is from Sloane (1), p. 61.

[b] Schwartz (1), p. 113.

[c] Davidson (1), p. 450.

[d] Hughes (1), p. 35.

[e] von Lippmann (4), p. 406.

[f] *Wu Li Hsiao Shih*, ch. 6, pp. 4b–5a for white earth, *TKKW*, p. 170 for yellow clay water, *MS*, ch. 150, p. 33a for fine smooth yellow clay and the *Kuang Yang Tsa Chi*, ch. 2, p. 66a for plain clay.

[g] For red clay see the +1503 *Hsing-Hua FC*, ch. 12, pp. 11a–11b, the +1530 *Hui-An HC*, ch. 5, pp. 20a–20b and for south Taiwan see Myers (1), p. 19.

[1] 白土 [2] 黃泥水 [3] 細滑黃土 [4] 泥 [5] 赤泥

aquatic plants to the surface of cones.[a] Jorges Chandra Ray undertook some washing experiments with *gur* for the purpose of observing and describing this process. He concluded that the plants employed contained no magical charms, and that the effect was a simple washing from the water in them. The major effects from claying were most probably also a simple washing action. Further evidence of this occurred in the account of Barbados entitled, 'The History of the Culture of the Sugar-Cane and the Making of Sugar' of c. +1667, submitted to Henry Oldenburgh, an early Secretary and organiser of the Royal Society:[b]

To whiten this sugar, after it hath run about a forthnight they digge up 2 or 3 inches from the broad top, where meeting with a crust, they raise it and beat it small with a woodden mallet to make it lye close and smooth with the rest; which done, they take a good clay (the whither the better) and, after it hath been well dried in the sun, mixe it with water, working and incorporating it so well together that they may not sever when this mixture is powred into the potts. Being by thus working it reduced to the consistency of a reasonable pancake batter, 'tis powred on the top of the potts two inches thick, by which means the remaining Molossus is forced downe from the Sugar and the Sugar made white; which will be effected in about 3 months time. If in a weeks time or so they find the clay dry on top, they must powre on more to make it worke; and by this means they can make 3 or 4 sorts of sugar, whereof that which lyes next to the Clay is the whitest and according to its distance from the clay they have their first, 2d, 3d and more degrees of whites.

Chinese sugar makers commonly mixed water with clay for coning, and an illustration depicting a jar labelled yellow clay water (*huang ni shui*) appeared in the *Thien Kung Khai Wu*, of +1637 (see Fig. 110).

Yet, some authors insisted that clay or white earth applied in various parts of the world did exercise some cleansing effect. Francis Willughby, who travelled through the sugar-producing areas of Spain in +1664, reported:[c]

These pots [sugar cones] are covered when full with a cake of past [paste], made of kind of earth called in Spanish *Gritto*, and found near Olives, which is good to take the spots out of clothes, which cap or cover sinks as the sugar sinks. [Mr Swift told me that the clay they use with us is tobacco-pipe clay or very like it, and that the water in the clay served to wash down and carry away the *Molossos*, at least the clay helps the separation and precipitation of it]

This fine clay patently contained some cleansing properties.

(iv) *Reboiling*

The combination of coning and claying had a number of significant effects. First, it made possible the manufacture of a great array of sugars from 'black'

[a] Watt (1), vol. 6, pt 2, pp. 31 and 254. Watt gave the names of the following aquatic plants which were used: *Hydrilla verticillata, Lagarosiphon roxburghii* and *Vallisneria spiralis*.

[b] Stearns (1), p. 181.

[c] Ray, John (1), p. 478.

to white. Second, these sugars provided the raw material for reprocessing into additional crystalline products. If economic conditions proved favourable, the black coloured sugars from the bottoms of the cones could be dissolved and reboiled with further clarification to produce more crystalline sugars. Alternatively, massecuite could be clayed in a cone. After about a week the clay was removed and the layer of white sugar closest to the top of the cone taken away and a fresh batch of clay applied to the sugar remaining in the cone. This process was repeated until the cone became empty. Subsequently the whole operation resulted in the production of a multitude of sugar types with an array of names. It is unprofitable to try to enumerate all the names, but a study of some +17th-century texts will elucidate the processes and problems involved.

A general idea of the claying process and the range of sugar products made in China can be gained from the *Min Shu* of +1631:[a]

[Introduction]

There are two types of sugar; black (*hei-thang*[1]) and white sugar (*pai-thang*[2]). [Within the white sugar category] there is double clear (*shuang-chhing*[3]) and pure white (*chieh-pai*[4]).[b] Melt and reboil (*lien*[5]) it to get sugar candy (*thang-shuang*[6]), also called ice sugar (*ping-thang*[7]) and honey pieces (*mi-phien*[8]), also known as cow's hide sugar (*niu phi-thang*[9]).

[Method]

First boil sugarcane juice and mix lime (*pai-hui*[10]) in with it to make black sugar (*hei-thang*). Next put it [the black sugar] inside a large drainer (*tshu lou*[11]), and wait until all of the molasses (*shui*[12]) has drained off, and then cover [the top of the sugar in the drainer] with fine smooth yellow clay (*hsi hua huang-thu*[13]). The sugar usually turns white in colour with three changes [of the clay covering]. There are three grades [of white sugar in the *lou*[14] drainer]; the white at the top is called clear sugar (*chhing-thang*[15]), the white in the middle is called official sugar (*kuan-thang*[16]) and that at the bottom is called wet tail (*fên-wei*[17]). The molasses (*shui*[12]) that drains out of the cone is known as sugar water (*thang shui*[18]).

Melt and reboil (*phêng lien*[19]) official sugar. Break the egg of a hen and stir it [into the syrup] to get the impurities to float to the surface. Once again put [the boiled syrup] into a drainer (*tshu lou*[11]) and cover it with clay (*thu*[20]) as before. The colour [of the sugar] turns even whiter and is called pure white sugar (*chieh pai-thang*[21]). The molasses (*shui*[12]) that drains off is called pure water (*chieh shui*[22]) [i.e. a higher quality molasses].

Further melt and reboil (*phêng lien*[19]) [the pure white sugar] to make *thang-shuang* and honey pieces (*mi-phien*).

This text elaborated the full sequence of white sugar-making technology. The whole gamut of white sugars from clear sugar (*chhing-thang*) through to the high-

[a] *MS*, ch. 150, pp. 33a–33b.

[b] *Chieh-pai* refers to higher quality sugar and molasses.

[1] 黑糖	[2] 白糖	[3] 雙清	[4] 潔白	[5] 鍊
[6] 糖霜	[7] 氷糖	[8] 蜜片	[9] 牛皮糖	[10] 白灰
[11] 甕漏	[12] 水	[13] 細滑黃土	[14] 漏	[15] 清糖
[16] 官糖	[17] 舊尾	[18] 糖水	[19] 烹鍊	[20] 土
[21] 潔白糖	[22] 潔水			

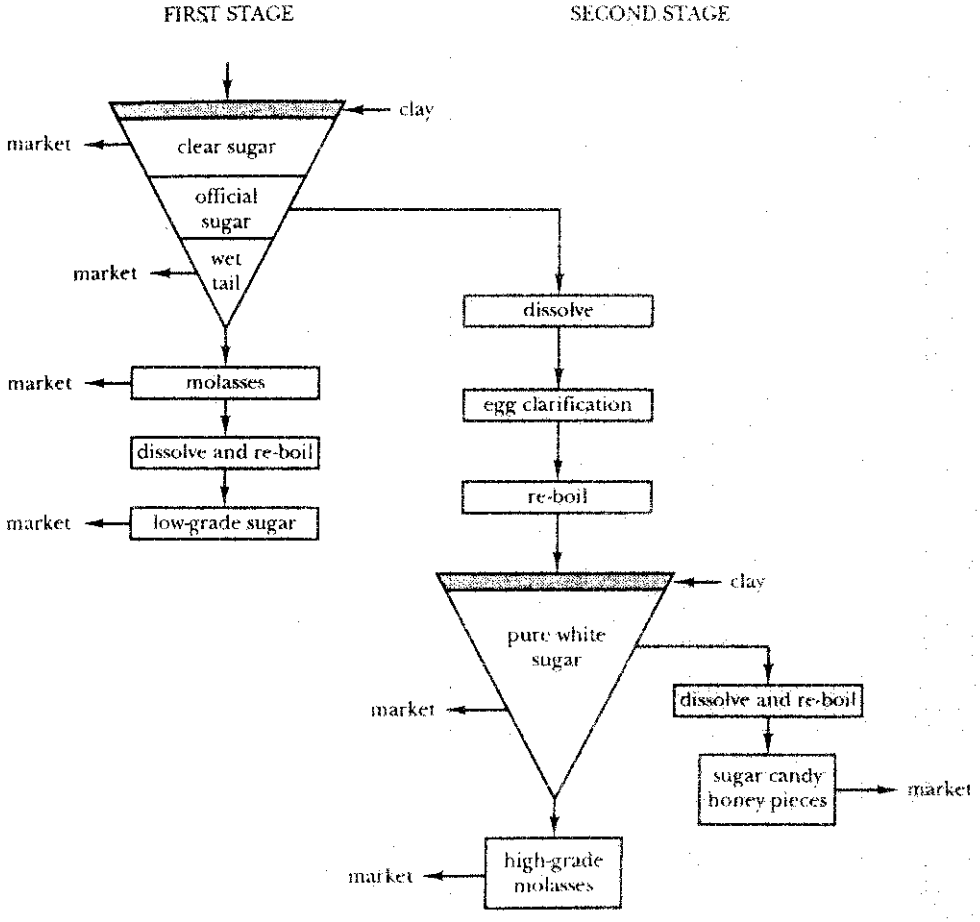


Fig. 111. A sketch of the Chinese method of manufacturing white sugar and sugar candy. This outline has been prepared from the account in the *Min Shu*, ch. 150, pp. 33a–33b, of +1631, which described a double-stage coning, re-boiling and claying sequence for manufacturing white sugar. In the first claying, black sugar (*hei-thang*[1]) yielded clear sugar (*chhing-thang*[2]), official sugar (*kuan-thang*[3]), wet tail (*fen-wei*[4]), and molasses (*thang-shui*[5]). Clear sugar, being the whitest at the top of the cone, was immediately marketed, and wet tail and molasses were either sold or dissolved and re-boiled to make a low-grade sugar for sale. Official sugar served as feedstock for the second stage in which it was dissolved, clarified, re-boiled and clayed to yield pure white sugar (*chieh-pai-thang*[6]) and a high-grade molasses known as *chieh-shui*[7] or, literally, pure water. Pure white sugar was either marketed, or dissolved and re-boiled to make sugar candy (*ping-thang*[8], *thang shuang*[9]) and honey pieces (*mi-phien*[10], *niu-phi-thang*[11]). This method of manufacturing white sugar involved one re-boiling and two claying sequences, but after the late +17th century, the second stage was often dropped, and the technique described in the *Wu Li Hsiao Shih* of +1664 was followed as a labour- and fuel-saving device.

est quality sugar candy, and honey pieces were made in a double coning reboiling and claying sequence (see Fig. 111). In the first claying, the raw material, black sugar, was drained and clayed to yield three end products and the feedstock, official sugar, for the second claying. The end products of the first coning

[1] 黑糖 [2] 清糖 [3] 官糖 [4] 蜜尾 [5] 糖水
[6] 潔白糖 [7] 潔水 [8] 冰糖 [9] 糖霜 [10] 蜜片
[11] 牛皮糖

Table 17. *Yields of clayed sugar, twice-boiled sugar and sugar candy from jaggery in India (expressed in a 100 units of jaggery)*[a]

No. of boilings	Units of sugar	Units of molasses	Units of loss
1	40 clayed sugar	47·5	12.5
2	15 twice-boiled loaves	65	20
3	10 sugar candy	70	20

[a] From Milburn (1), Vol. 2, p. 271.

included clear sugar, which could be marketed as it was, and wet tail (*fên wei*) and molasses, both of which could be sold in that state, or reboiled to make lower-grade sugars. For the second claying official sugar was dissolved and clarified with eggs. It resulted in pure white sugar and a high-quality molasses. Pure white sugar could be either sold, or dissolved and reboiled to make sugar candy and honey pieces. With each reboiling and claying the sugar attained greater purity, with more sucrose and less impurities (see Table 17). It is easy to understand that the market price would rise with each stage of the process with the extra labour and fuel energy expended.

Another procedure emerged in which the process was expedited by repeated application of clay with continuous removal of the top sugar as it whitened. The coning and claying sequence proved quicker, and saved more labour and fuel than the *Min Shu* method. An unidentified source, cited in the *Wu Li Hsiao Shih* of +1664, described the procedure:[a]

Double clear (*shuang-chhing*[1]) and sugar candy (*thang-shuang*[2]) are top [quality sugars] and wet tail (*fên wei*[3]) is of the lowest [quality]. In the tenth lunar month filter (*lü*[4]) sugarcane and its juice will be ready for concentrating (*ning*[5]). Put it into a cauldron (*fu*[6]) and boil it until it has crystallised (*ting*[7], [lit. fixed]). Take an earthenware drainer with a pointed base (*jui ti wa ying*[8]), make a hole in the bottom, and place [black sugar] inside it. Position [the earthenware drainer] over a large earthenware jar (*kang*[9]), and wait until [the molasses] has dripped down out of the hole before covering the top of the sugar [in the earthenware drainer] with a layer of fresh yellow clay (*hsien huang-thu*[10]). If drained for a long time, the impurities [on the sugar] at the top [of the earthenware drainer] will be completely removed, and [the sugar] will become extremely white. This is double clear. Next clear (*tshu-chhing*[11]) is what is left over from repeated draining, applying and removing clay (*lü ti kai chhu*[12]).[b] [The sugar] almost black is the so-called wet tail (*fên wei*).

To make skin sugar (*phi-thang*[13]) place pieces of bamboo in an earthenware jar (*wêng*[14])

[a] *Wu Li Hsiao Shih*, ch. 6, pp. 5a–5b.
[b] This line indicates continuous claying in the same cone.

[1] 雙清 [2] 糖霜 [3] 濱尾 [4] 濾 [5] 凝
[6] 釜 [7] 定 [8] 銳底瓦罌 [9] 坩 [10] 鮮黃土
[11] 次清 [12] 屢滴蓋除 [13] 皮糖 [14] 甕

and pour the boiled sugar into it. [Later] invert the earthenware jar to drain the leftovers. That which dries on the bamboo is skin sugar.

The two procedures differed in that the *Wu Li Hsiao Shih* method only included one reboiling of the sugar to make the best quality product, ice sugar, while the *Min Shu* technique required two reboilings (see Fig. 111). Because of the saving in labour and fuel one would suppose that the *Wu Li Hsiao Shih* method achieved prominence. Gazetteers indicated that sugar makers widely practised it in Taiwan during the +18th century.[a]

Chinese sources give us some idea of the time required to make one batch of white sugar. The *Min Shu* passage quoted above and the *Tung Ning Cheng Shih Chi*[1] of the late +17th century recorded that clay was applied to sugar in the cone for a total of three times.[b] The *Thai Hai Shih Chha Lü*[2] stated that it took over thirty-five to forty days from the initial draining and first application of clay until white sugar finally formed in the cone.[c]

(v) *Quality of Chinese sugar on the European and Asian markets*

How efficient were the Chinese in producing sugar to satisfy the quality demands of the European market?. One way of trying to assess the situation is to compare the price of Chinese and other sugars on the European market on the assumption that price is indicative of quality. Glamann has assembled data concerning the price of sugar on the Amsterdam market during the +1630s, and it is instructive for making comparisons with Chinese sugar. I have re-arranged the data in Glamann (1) to include only the years when East India sugar was Chinese (from Taiwan) in origin, see Table 18.

Chinese sugar listed in Table 18 was either made by Chinese in south Taiwan, which the Dutch controlled from +1624 to +1662, or imported from China, and both were shipped to Amsterdam via Batavia. The data can only be considered indicative for we do not understand the different price structures of the sugar market in East Asia and Europe. Nonetheless, it is evident that on the basis of price, Chinese sugar candy rated far lower in quality than that manufactured in Europe. By the same principle Chinese powder sugar, most probably clayed sugar, sold at prices equivalent to muscovado from the West Indies, but below Brazilian clayed sugar. Both Chinese grades suffered the disadvantage of greater shipping time, with consequent delay resulting in deterioration. The sea voyage from Batavia to Holland required ten months alone, without adding the extra time for shipment from China.[d] In contrast the journey

[a] +1720 *Thai-Wan FC*, p. 53.
[b] *Tung Ning Cheng Shih Chi* quoted in the *THSCL*, p. 56.
[c] *THSCL*, p. 57.
[d] Glamann (1), p. 155.

[1] 東寧政事集 [2] 臺海使槎錄

Table 18. *Amsterdam sugar prices +1632, +1633, +1634 and +1637 fl. per pond*

	White candy	Refined sugar	Loaf sugar	Brazilian white	Muscovado	Chinese candy	Chinese powder
+1632	1.14	0.80	0.74	0.70	0.54	0.71	0.54
+1633	1.12	0.80	0.75	0.67	0.54	0.49	0.40
+1634	1.11	0.77	0.73	0.66	0.50	0.49	0.47
+1637	1.36	1.06	1.02	0.85	0.67	0.83	0.70
Mean	1.18	0.86	0.81	0.72	0.56	0.63	0.53

Modified from Glamman (1), table 28, p. 154

from Salvador in Brazil to Lisbon could be as short as thirty days in summer and only eighty-five days in the worst winter conditions.[a] At the time of shipment, Chinese clayed sugar from Java probably equalled European plantation clayed sugar in terms of quality. However, Chinese sugar candy from Taiwan, which had a longer 'shelf life' than ordinary clayed sugar, evidently was not as highly appreciated as its European counterparts in the +1630s. After their expulsion from Taiwan, the Dutch encouraged the Chinese to produce sugar in Java. Glamann related that c. +1683 Batavian sugar was clearly more highly appreciated by the Dutch East India Company than that from Bengal.[b] Both surpassed Siamese sugar which fetched very low prices c. 30fl. per pond on the Amsterdam market, if accepted at all.[c]

During the +18th century Chinese-made sugar derived from China, Manila and Batavia remained superior to Bengali, and claimed a large share of the market.[d] In addition, Glamann demonstrated that between +1680 and +1709 the Dutch East India Company established outlets for Chinese manufactured Javan sugar in Europe, Japan, Persia, Surat, Malabar and Coromandel.[e] These markets continued to flourish into the mid +18th century.

Rondot furnished detailed information concerning sugar quality in south China in the +1840s.[f] He compared the best Chinese sugar candy to that of the French Laboratories, and distinguished four grades of descending quality from grade 1 (limpid, transparent white) to grade 4 (opaque and light brown).[g] This indicated a great range of quality control, which was probably evident in the +17th century, and reflected in the lower prices on the European market (see Table 18). Rondot discussed white sugar and made the point that we have alluded to earlier; colour was not related to method of manufacture.[h] White sugar, *pai-thang*, on the Kuang-Chou market during the early +19th century,

[a] Schwartz (1), p. 182, map 3.
[b] Glamann (1), p. 160 and table 30.
[c] *Ibid.*, p. 154, p. 160 and table 30.
[d] Milburn (1), vol. 2, p. 271.
[e] Glamann (1), p. 161.
[f] Rondot (1), pp. 204–7.
[g] *Ibid.*, p. 204.
[h] *Ibid.*, pp. 204–6.

was manufactured either by claying or simple draining (i.e. well-clarified muscovado). These clayed and drained sugars were of good even quality and yielded only 15 per cent molasses on refining. Yellow sugar (*huang-thang*) manufactured by the *sha-thang* process displayed great variability in quality. Rondot cautioned that *sha-thang* should only be purchased *avec prudence*. *Hei thang* and an unidentified *kip-thang*, the two lowest-grade sugars which varied from brown to black, were largely sold on the Chinese domestic market. I believe that the Rondot survey probably indicated the market quality in south China for a few centuries prior to the +1840s.

(vi) *Other sugars*

Next let us turn to a number of other speciality sugar products. In China sugar fashioned into the shapes of animals became a feature of epicurean culture, but its origin remains uncertain as we demonstrated in (b), above. The *Thang Shuang Phu* of c. +1154 first recorded such shapes and attributed their provenance to demands by officials for the rare and exotic.[a] Regardless of whether these shaped sugars originated in the Sung or earlier, they were clearly made in the same way as sugar candy; that is by utilising the cold to grow crystals onto miscanthus and bamboo frames placed in the jars. The *Thang Shuang Phu* mentioned the use of moulds for shaping medicinal cakes, as we saw earlier on pp. 69–70, but the first major source for them was the +17th-century work, the *Thien Kung Khai Wu*:[b]

To make sugar in the shapes of animals, fill a large cauldron with fifty *chin*[1] [30 kilos] of sugar (*thang*[2]) and boil it slowly under a slow fire. The surface of the sugar syrup will come to the boil (*thang thou kun hsüan êrh chhi*[3]), if the fire [is applied] from one side of the cauldron, [but] will suddenly boil over (*chin chin fu*[4]) and spill onto the ground, if the fire is placed below the centre of the cauldron.[c] Dissolve the whites of three hen's eggs, without the yolks, into five *sheng*[5] (5.2 litres) of cool water, and use a spoon to add [this clarifier] slowly to each cauldron. After heating, foam and black scum (*fu ou hei tzu*[6]) rise to the surface, and are skimmed off with a rattan scoop. The syrup, after becoming exceptionally clear and white (*chhi thang chhing pai chih shên*[7]), is ladled into a copper pot (*thung tiao*[8]) which is heated by a slow fire made with coal briquettes (*tzu fêng*[9]). After judging that [the syrup] has been boiled for the correct length of time pour it into the moulds (*mo*[10]).

Moulds for making sugar in the shape of lions and elephants are composed of [two pieces of pottery], which fit into each other like [two half] tiles. The syrup is ladled into the mould, and the latter is immediately turned around and around, [an action

[a] *TSP*, pp. 5b–6a. Translation of relevant passage given in (*b*), above, pp. 74–5.

[b] *TKKW*, pp. 171–2.

[c] As Yabuuchi ((*11*), pp. 126–7) has pointed out this is very rational advice. It is difficult to bring a dense liquid like syrup to the boil by heating the container directly from below. Also, once it exceeds the boiling point, the syrup suddenly boils up violently, and may cause the container to crack and the syrup to escape. This phenomenon is known to chemists today as bumping.

[1] 斤 [2] 糖 [3] 糖頭浪旋面起 [4] 盡盡沸 [5] 升
[6] 浮漚黑滓 [7] 其糖清白之甚 [8] 銅銚 [9] 白風 [10] 模

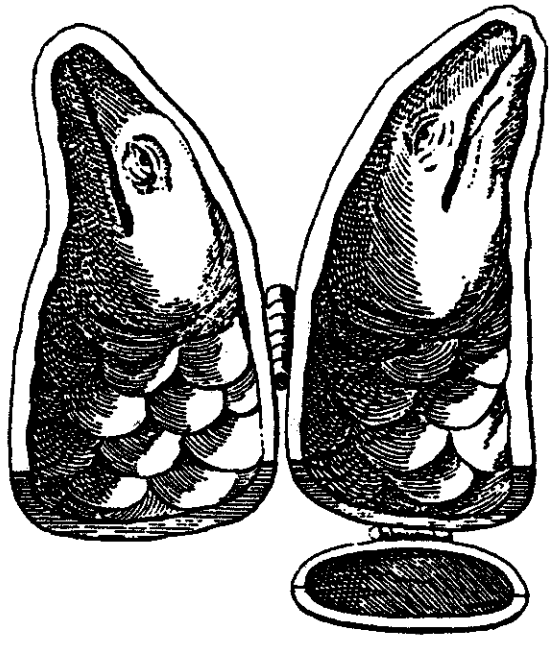


Fig. 112. A mould for fashioning sugar into the shape of a fishhead replete with scales; the *Encyclopédie* of Diderot through Gillispie (2), Confectioner's III. Moulded sugar shapes were common throughout Asia and Europe in the pre-modern period.

which causes excess syrup] to flow off. Since the mould is cold and the syrup boiling hot, a layer of sugar naturally solidifies on the [inside wall] of the mould. This is known as feast candy (*hsiang thang*[1]) and is consumed at banquets.[a]

This source outlined a different method of manufacture to the *Thang Shuang Phu*; here sugar makers melted and reboiled sugar with egg clarification and shaped it with the aid of moulds. The finer clarification undoubtedly yielded a superior confectionery by a more reliable method than that of the *Thang Shuang Phu.*

Confectioners in many parts of the world dyed sugar. It was rare in China and I have only found one reference to it. The 1884 gazetteer for Chao-Yang county[2] in north-eastern Kuang-Tung reported that yellow sugar (*huang-thang*[3]) was dyed bright colours (*jan-tshai*[4]).[b]

(vii) *Review of sugar and general crystallisation techniques*

In Volume 5, part 4, the subject of crystallisation is discussed, and in particular saltpetre, potassium nitrate in some detail. Joseph Needham remarks:[c]

[a] Moulded sugars were popular in +18th-century Europe, and Diderot included a plate of moulds for making them in his celebrated *Encyclopédie*, see Fig. 112.

[b] 1884 *Chao-Yang HC*, ch. 12, p. 27a.

[c] Vol. 5, pt 4, p. 190.

[1] 享糖 [2] 潮陽縣 [3] 黃糖 [4] 染采

But if one thing more than any other comes out crystal clear from this account, it is that methods for the collection and purification of potassium nitrate were steadily developing during the seven centuries preceding the first knowledge of the salt in Islam or the West, i.e. between +500 and +1200; and probably during the last three or four of these, i.e. from the late part of the Thang period, it was being turned out on a manufacturing scale by artisans who achieved a fairly constant product but were not able to explain to the scholars exactly how they did so.

With sugar, knowledge on crystallisation dated from about the time of Christ in India, when artisans employed clear-cut practical methods. They found that rapidly beaten supersaturated syrup formed a fine-grained soft sugar, and the heat of crystallisation removed most of the moisture. Consumers found these fine sugars desirable because of their pleasant taste. About the same time they discovered that sucrose could be crystallised from impure syrups leaving most of the impurities in the mother liquor, which could be separated with suitable drainage apparatus. The so-called 'technological mission' discussed earlier transmitted these innovations to China during the mid +7th century. Joseph Needham noted in Volume 5, part 4 that 'by the beginning of the +8th century at least, the sulphates of sodium and magnesium had been separated by differential crystallisation and were being used in medicine'.[a] These datings are highly suggestive of sugar making leading the general art of crystallisation in China.

An examination of the sugar-candy technology introduced into China in the +8th century, as documented in the *Thang Shuang Phu* of c. +1154, reinforces this proposition. The use of bamboo slips to provide resting places for sugar crystals to grow was clearly recorded for the +12th century.[b] In addition, the *Thang Shuang Phu* carried a description of the growth process of large sugar crystals, and even has a phrase for the process, fruiting or *sui kuo-tzu chieh shih*[1]:[c]

After the syrup (*thang shui*[2]) has been in the jar for two days, it resembles the pattern of congee. By taking some on the finger and feeling it you will see that it is similar to small crystal sand (*hsi sha*[3]). After the fifteenth day of the lunar new year [i.e. after about two months in the jars] small lumps form and [sugar crystals] also conglomerate on the ends of the bamboo slits like ears of millet. [The crystals] gradually get as large as a bean or even a knuckle. The enormous ones are as large as miniature mountains. [This growth process] is commonly known as fruiting (*sui kuo-tzu chieh shih*[1]).

Since the crystals do not grow any larger after the fifth lunar month when the cycle of crystal formation and growth completes itself (*chhun sheng hsia chang chih chhi i pei*[4]), drain the jars. (If not drained before the beginning of summer, [the sugar] will turn to molasses (*shui*[5]). Minor households hurriedly try to drain beforehand in the fourth lunar month). Molasses (*thang shui*[2]) still remains there amongst the sugar candy that has

[a] Vol. 5, pt 4, p. 190.

[b] This may be an ancient art as the generic technology appeared in the Han. The *Huai Nan Tzu* (presented to the throne −139) recorded an old basket as a focus for crystallisation, see Vol. 5, pt 3, p. 25.

[c] *TSP*, pp. 4b–5a; Liu & Liu (*1*), pp. 15–16.

[1] 隨果子結實 [2] 糖水 [3] 細沙 [4] 春生夏長之氣已備 [5] 水

formed, [so the jars have to be drained]. The jar is drained by scooping out the molasses with a ladle, taking the sugar candy and draining it dry.

Clustered branch (*thuan chih*[1]) crystals that grow on the ends of the bamboo slits, are cut for draining according to their size. [After] the draining is completed, [the clustered branches] are laid out under strong sun rays to dry. Once very dry store them away in a jar.

Crystals that grow around the sides of jars are called glossy jar (*weng chien*[2]). [Crystal] grain and lumps protrude out in layers like stalactites in craggy caves. But they grow sideways and cannot be drained immediately. Draining [therefore], must be done by [leaving the sugar] in the jar and exposing it to the sun for a few days until it is dry and hard. [These crystals] are removed [from the jar] by gradually separating them into several pieces with a steel scraper.

The quality and colour of sugar candy in a jar is naturally different. The best is [a conglomerate of crystals] piled up like miniature artificial mountains, next followed by clustered branch, next glossy jar and next small grain lump (*hsiao kho khuai*[3]). The lowest grade is sandy bottom (*sha chiao*[4]). Purple is regarded as the best [colour], next deep amber followed by light yellow. Light white is the least liked.

Irrespective of the size [of the crystals, one of the] most prized [types of sugar candy] is commonly called horses teeth sugar candy (*ma chhi shuang*[5]), [the crystals of which are] grown close together on the wall of the jar (*chhiang pi mi phai*[6]). Any sandy bottom covering the surface is scraped off. There are also large lumps some weighing ten to twenty *chin*[7] [6 to 12 kilos]. The most unusual ones attain thirty *chin* [18 kilos]. The sandy bottom in the middle [of the jar at the bottom] is called abandoned (*shê*[8]).

This passage depicted the great range of different shapes of sugar crystals that formed on the side of the jar, and exposed a clear practical knowledge of the process of crystallisation.

(7) Packaging, Storage and, Transportation of Sugar

A suitable method of packaging was a precondition for sugar becoming a commodity. Nothing is known about packing methods prior to the Sung dynasty, but since sugar was sent from Chiao-Chih as tribute during the +2nd and +3rd centuries, and even imported from central Asia as a luxury during the Thang, we can assume that packing techniques for long-distance transportation had been devised. Trade in sugar probably remained of minor importance prior to the Sung as Wang Gungwu did not mention it in his exhaustive study.[a] Before that time sugar products were probably distributed locally and certainly within China.

Written evidence for the ability to pack sugar and keep it intact during transportation over long distances first appeared in the Sung. The *Thang Shuang Phu* specifically mentioned the method of packing sugar candy:[b]

[a] Wang (1).
[b] *TSP*, p. 5a; Liu & Liu (1), p. 16.

[1] 團枝 [2] 甕鑑 [3] 小顆塊 [4] 沙脚 [5] 馬齒霜
[6] 牆壁密排 [7] 斤 [8] 舍

Method of storage: Spread dry barley and wheat on the bottom of the jar, and place a bamboo basket with a [base covering of] closely packed bamboo rind over it. Store [the sugar candy in the basket, protecting it on top] with raw cotton, and stack another bamboo basket [on top again]. [When full] cover the jar with a sieve.

Put several lumps of lime on the bottom of the jar when sending to distant places. Store [the sugar candy] on paper (*chih*[1]) placed over the lime. Firmly secure the mouth of the jar.

The *Pên Tshao Yen I* of +1119 wrote of the preservation of *shih-mi*:[a]

Much [of the *shih-mi*[2]] naturally dissolves during the long continuous rains of the summer months. The local people first wrap it in bamboo leaves and paper, and bury it with lime (*shih chia*[3]). It is not exposed to the atmosphere (*fêng*[4]), and thereby avoids [dissolution].

The method of packaging later turned into the unit by which Sung merchants traded sugar; the *Thang Shuang Phu* and the *Thieh-An Chi*[5] of the Southern Sung by Fang Ta-Tsung[6,b] confirmed that the jar served as the unit of trade in such geographically separated areas as Fukien and Ssu-Chhuan.

In parts of India during the +16th century merchants packed sugar in leather. Duarte Barbosa wrote about the sugar trade in Bengal in the year +1518:[c]

Much good white *sugar* is also made here from canes; but they know not how to compress it and make it into loaves; so they wrap it as powder in parcels of untanned leather, well sewn. Great store of this is taken in cargoes and carried for sale to many lands, for it is a principal article of trade.

In China sugar may have been packed for export in cow's hide during the +17th century, as the *Min Shu* of +1631 listed cow's hide sugar (*niu phi thang*[7]) as an alternative name for honey pieces (*mi phiên*[8]).[d] In the +1680s Chinese merchants exported *phi-thang*, or hide sugar, made by Chinese in Quang-Nam[9] in central Vietnam to Japan.[e] Cow hide could have been a special export packing for honey pieces.

Rondot furnished some specific information on packaging at Canton during the 1840s. He noticed that packaging varied with the quality of the sugar. Sugar candy was packed in wooden tubs, trimmed inside with fresh banana paper and covered outside with glazed paper, that held half a picul (about 30 kg). Merchants always despatched *ping-hua*[10] in wooden chests, while they indiscriminately packed other cheaper sugars in chests, sacks or mats. Chests were only customary for best grades, 'and are only rarely demanded'.[f]

[a] *PTKM*, p. 1891.
[b] *Thieh-An Chi*, ch. 21, p. 4b.
[c] Barbosa (2), vol. 2, p. 146
[d] *MS*, ch. 150, pp. 33a–33b.
[e] *Ka I Hentai*, pp. 1035–1036.
[f] Rondot (1), p. 207.

[1] 紙 [2] 石蜜 [3] 石灰 [4] 風 [5] 鐵菴集
[6] 方大琮 [7] 牛皮糖 [8] 蜜片 [9] 廣南 [10] 冰花

Chinese overseas also transported sugar in sacks. John White, who visited Saigon from 1819 to January 1820, recorded that sugar sacks weighed over a picul (roughly 60 kg):[a]

> The Cochin Chinese sugar comes from the country in large matting sacks, containing somewhat more than a picul each, generally; when shipped they are covered with an additional sack, the ends of which are secured with strips of split rattan. Every sack should be pierced in several places with a *boomar*, an iron gimlet made for the purpose to prevent imposition.

The same writer in his 1819 visit to the Philippines observed the Chinese bringing sugar into Manila from the plantations in pilons, 'which are large earthen vessels, three of them contain two piculs [120 kg].'[b]

(8) Conclusions on Manufacture

The art of sugar making commenced in India from the time of Sidhartha Gautama, the Buddha, about −500. The first product *phāṇita*, a concentrated syrup, was stable because of the high osmotic inhibited pathogens. An amorphous sugar, *guḍa*, appeared next, and it was made by boiling off water and letting the mass set solid. This technology seemed to have extended across South-East Asia and south China by −200. The Han Chinese knew syrup as *chê-chiang*, and amorphous sugar as *shih-mi*. At the time of European contact there was a Pan-Asian type of sugar-making technology for amorphous sugar common to the area covered by present-day Burma, Cambodia, Laos, Vietnam and south China.

The methods for expressing juice varied, and included the mortar and pestle, pressing boards, and even arrangements where sugarcane was crushed with a flexible pole set in a tree stump as shown in Fig. 56. In the −1st century the Indians developed some new products. They found that if a supersaturated syrup was allowed to crystallise the amorphous sugar achieved a definite crystal structure that allowed it to be rolled into balls or made friable by sun drying. This sugar was the *gur* of modern India and the *hei-thang* of pre-modern China. In the first centuries of our era the Indians discovered that a soft grain sugar resulted if a supersaturated solution was beaten with a paddle. Called *khaṇḍa* in India and *sha-thang* in China, it achieved great popularity in Asia because of the readiness with which it could be made. The Indians also discovered that if a large grained *gur* was drained, a hard grained sugar *śarkarā* remained in the drainer; the molasses which ran off could be eaten or fermented for alcohol. These techniques, combined with some clarification, resulted in a range of colour from white through yellow and brown to black. By clarifying the juice with high temperature and the addition of milk, impurities became trapped in scum which sugar boilers skimmed.

[a] White J (1), p. 333.

[b] *Ibid.*, p. 133.

Such were the techniques practised in India during the first few centuries after Christ. These techniques spread to Persia and by the Sui dynasty at least, China imported *śarkarā* (*shih-mi*) as a luxury. The soft sugar, *sha-thang*, was also mentioned in the Chinese translations of Buddhist texts of about +500, indicating a knowledge of this sugar.

None of these clarified, drained and beaten sugars was made in China prior to the +7th century when the first signs of their local production arose. It is hard to date exactly when they were introduced from India; the most well-known hypothesis being the controversial Chinese technological mission to India in +647. As we have demonstrated, though the Chinese annals portrayed this mission as proceeding at the express wishes of Emperor Thai-Tsung, Indian sugar-making techniques were most probably transmitted through the agency of Buddhists from the Mahābodhi temple at Bodh Gayā, located near the Bodhi tree under which the Buddha gained enlightenment. Members of the Buddhist *saṇgha* may have volunteered an expedition to China, or may have been requisitioned by Wang Hsüan-Tshê who led the Chinese mission to Magadha. Judging from the Tun-Huang manuscript P 3303 dating from the +9th to +10th centuries we surmise that Buddhists on the mission and in subsequent periods transferred the art of making beaten soft sugar, *sha-thang*, hard crystal grained sugar, *shih-mi*, as well as the milk clarification which improved the grade and whiteness of all sugars.

The only other early sugar, sugar candy, was probably discovered by accident in India by the time of the *Śuśruta Saṃhitā* and the Bower manuscript in the +4th century. Concentrated syrup left for a time in the cold of a north Indian winter would produce large candy crystals. It was not until the +8th century at least before sugar candy arrived in China, where it assumed the names sugar frost (*thang-shuang*) and ice sugar (*ping-thang*).

The Tun-Huang manuscript P 3303 confirmed the types of sugar technologies introduced from India, and indicated that the *kolhu*, an animal-driven mortar and pestle, operated in China during the +9th and +10th centuries. However, the Chinese possessed their own more appropriate extraction technology for extracting oil from seeds, which they applied to crushing sugarcane in preference to the Indian device. The Chinese oil mill consisted of a large edge-runner for the primary crushing of the seeds to obtain the highest-grade oil. The crushed residue then underwent steaming and extraction again in a static press. This secondary press cannot be identified with certainty, but was either a rope-clutch or a tackle-and-weight press. The edge-runner (see Fig. 65) continued for oil extraction until the late 19th century when Alexander Hosie documented it for soya beans in Manchuria (Hosie (6)). Sugar makers successfully adapted a primary crushing with an edge-runner and secondary pressing steaming procedure for pressing sugarcane by the Sung dynasty, when the *Thang Shuang Phu* of c. +1154 elaborated it for the first time. This type of technology diffused westwards from China. The excellent description and drawings

in Wulff (1) leave no doubt that the 20th-century Iranians practised this technology for oil extraction. The only difference in the Iranian process was that the secondary pressing lacked a steaming procedure. The Muslims carried the edge-runner throughout the Middle East and North Africa to Morocco and Spain. Berthier found archaeological evidence of the edge-runner in Morocco in the +16th century (Berthier (1)), while in Spain Francis Willughby described it on his travels in +1664.[a] In pre-modern Europe the edge-runner worked at such widely divergent tasks as grinding dyes, making cider and gunpowder. It diffused to the New World where it did a range of jobs including grinding indigo leaves (see Fig. 2), crushing sugarcane, and grinding ore.[b] The edge-runner was clearly a major invention that, more than any other, was responsible for increasing efficiency in a number of agricultural extraction processes.

The invention of the roller mill from the cotton gin signalled the next major development in agro-industries. The cotton gin dated to about +1100, had two rollers independently powered by hand that allowed the cotton fibre to proceed through the rollers, but would not admit the seed which remained on the feeding side. I have been able to trace the subsequent evolution of the cotton gin to two different machines, the sugarcane roller mill and the metal rolling mill. The horizontal, sugarcane roller mill is merely a scaled-up cotton gin (compare Fig. 71 with Fig. 73). The dating from literary evidence of c. +1100 for the cotton gin and +1570 for the first horizontal roller mill in the Canaries in the *Rerum Medicarum Novae Hispaniae Thesaurus, seu Plantarum, Animalium, Mineralium Mexicanorum Historia* of Francisco Hernandez leaves no doubt that the sugarcane mill derived from the cotton gin and not *vice versa* as suggested by Haudricourt and Dumas.[c]

I have endeavoured to show pictorially the evidence for the evolution of metal rolling mills. The first real evidence for metal rolling mills appeared in the later +15th century with Leonardo da Vinci. I have compared cotton gins from India and the New World with Leonardo's designs (see Figs. 71, 81a, 81b, 83a, 83b and 84) and the possible transmission of the idea is clear. Similarly, I have compared the Chinese, as well as Indian, types of cotton gin with a metal roller in the *Voarchadumia* of +1530. The various types of cotton gin that diffused from India were the obvious ancestors of the metal rolling mill, and the sugarcane roller mill was not their ancestor as a number of scholars have suggested.[d]

The first evidence of the horizontal sugarcane roller mill in Europe appeared with Francis Willughby in +1664, though Europeans still employed edge-runners in Spain during the +17th century. Yet the New World has an early history of the horizontal mill from about +1530 when mill inventories begin to list rollers. The question arises as to whether the horizontal sugarcane roller

[a] Ray, John (1), pp. 466–99.
[b] See plate 22 in A. F. Frezier, *A Voyage to the South Sea* of +1717 reproduced in Spate (1), p. 187.
[c] Haudricourt & Dumas (1), p. 104.
[d] Smith, C. S. (1), Jenkins, Rhys (4) and Larke (1).

mill in the New World was a transmission from India, or from the fledgling metal rolling industry of Europe, or yet again, a New World innovation from the cotton gin. This cannot be answered with any certainty as yet; if Indian engineers devised the roller mill as early as +1400 as I suggest, it could have been transferred to the Portuguese colonies in the Atlantic from India in the early +1500s. The international financial entrepreneurs, the Welsers, owned sugar plantations on Madeira, and in addition their headquarters were at Augsberg, where the first practical applications of rolling machines to minting coins took place. In +1513 they built a sugar mill in the Canaries, a time scale that would allow the transfer of the concept of roller milling, if their crushing machine indeed was a roller mill. On Hispaniola, colonists harvested naturally grown cotton and ginned it at the same time as the first sugarcane mills (type unknown) were erected. The fact that the generic concept of roller milling was prominently displayed points in the direction of possible stimulation from Europe rather than Asia.

Turning from India and Europe I find no evidence for two-roller horizontal mills in China, though they were recorded in countries overseas to which Chinese technology spread. I have speculated on their presence in China on the basis of such circumstantial evidence as the observation, by von Humboldt, of horizontal apparatus and a shed housing a mill, that he saw in a Chinese painting in Peru.

The next major development encompassed mounting the rollers in a vertical rather than horizontal position. The virtue of the vertical roller mill in premodern engineering was that the juice flowed away down the rollers and did not become reabsorbed in the exiting bagasse. The vertical roller mill was perhaps one of the most productive inventions of mankind for agricultural processing. Vertical roller mills in Asia and the New World crushed millions of tons of sugarcane from their invention in the +16th century until the advent of steam power, when they were replaced by horizontal mills, which proved easier to drive with steam, and safer for the operators as they could be fed from chutes.

The origin of the vertical roller mill remains obscure. The first evidence for it appeared simultaneously in the West and in the Philippines in +1613. A manuscript deposited in the Ajuda Palace in +1613 depicted it in a three-roller configuration; this mill was invented in Peru and transferred to Brazil by a Spanish priest. The vertical-roller Chinese form appeared in the Philippines in +1613, and shortly later was illustrated and described in the *Thien Kung Khai Wu* of +1637. Nevertheless, the fact that a vertical, two-roller mill must necessarily have preceded the three-roller version, prompts us to hypothesise that the vertical, two-roller mill was devised in China from a horizontal, two-roller prototype introduced from India at the time of Cheng Ho's last voyage in +1433, or perhaps later. The Jesuits and the Manila Galleon subsequently transferred it to the New World, where it is still found in the 20th century. Shortly afterwards the Jesuits in Peru devised the three-roller mill. The Jesuits commanded a

world-wide information system with its headquarters in Rome and correspondents in India, China, the Philippines and throughout the New World. They established large plantations in Mexico and Peru, where they cultivated and processed sugarcane under general *instrucciones* from Rome. The Jesuit contribution to technology transfer has been underestimated because authoritative scholars have asserted that early plantation America inherited a mature plantation technology from the Mediterranean area. The centrepiece of this technology was supposed to be the vertical, three-roller mill, for which such historians of sugar as Edmund von Lippmann and Nöel Deerr claimed a +1449 origin in Sicily with Pietro Speciale, and a myth arose that the New World displayed no technological development. Yet our investigations have demonstrated considerable technological variety and innovation in this region. After +1600 we see a progression from the edge-runner to the horizontal, two-roller mill and finally to the vertical, three-roller mill. In addition, most histories of sugar technology applauded as great improvements the 'Jamaica train' for conserving fuel and the subsider for clarification. The Brazilian researchers Gil de Methadio Maranhão and Moacyr Soares Pereira first exploded this myth (Methadio Maranhão (1), Soares Pereira (1)) but their findings passed unnoticed by English-speaking researchers until reported in Galloway (1). Such was the prestige of von Lippmann and Nöel Deerr (von Lippman (1), Deerr (1)) that the matter remained a controversy until put to rest in Daniels & Daniels (4). The Jesuit contribution has been neglected because most studies have concentrated on the +18th century by which time the situation had changed. Mörner (1) has summarised research to show that though the +18th century Jesuit estates were probably better managed than most contemporary New World plantations, they were not more advanced technically. This was certainly true by this time, but scholars have lacked necessary data for assessing earlier contributions.

Proceeding to the processing of the juice let us look at clarification techniques. Milk clarification, which originated in India, reached China by the +6th century. This provided a technique for making very white sugar from an early stage. Yet, it has been difficult to trace the origins of the outstanding clarifying agent, lime, which had world-wide significance for sugar manufacture after the +18th century. The first literary references appeared in China and Europe simultaneously in the *Thien Kung Khai Wu* and Angelus Sala's *Saccharologia*, both of +1637. Both areas plainly had a previous history, and it is hard to assign priorities. Nevertheless, China had a clear priority in manufacture of raw sugar as Angelus Sala only mentioned it for refining, and it was the mid +18th century before planters in the West Indies employed it for clarification. Prior to +1726, probably sometime in the late +17th century, the Chinese devised the precipitation bucket, an important utensil that revolutionised the clarification of sugarcane juices. They discovered that if juices were limed in a bucket and then allowed to stand, a heavy precipitate would sink to the bottom and scum rise to the surface, and the clear juice in between could be drained off. This was

the ancestor of the modern subsider,[a] which John Proculus Baker apparently discovered independently in +1775 in Jamaica.

I now come to the boiling of extracted juices. The transfer to China of the Indian technology of heating several pans in a row by a single fire probably dated back to the Tun-Huang manuscript P 3303 which mentioned as many as fifteen. By the +17th century the Chinese reduced the number of pans to three, and arranged them in an isosceles triangle rather than a straight line as the Indians. The pans were bricked into a single furnace and the rims raised with masonry to effectively enlarge their holding capacity by two feet. Pictorial evidence indicated that the Dutch conveyed this technology to Brazil after they occupied the northern areas from +1630 to +1654, where they were known as Dutch ovens. The arrangement leaves little room for doubting that the 'Jamaica train', which surfaced on Barbados in +1657 and on St Christopher in +1658, derived from the Dutch ovens, which in turn came from China, probably through the agency of one of the Dutch East India Company's trading stations in South-East Asia or Taiwan.

Crystallisation of syrup into massecuite and the draining of syrup to make *śarkarā* or muscovado sugars in about the +1st century marked the first big step forward in sugar refining. The Islamic world improved upon Indian draining techniques by inventing the cone about +1200. Sugar can be readily removed from cones by up-ending, and with small cones the sugar loaves can be 'baked' in an oven. The cone drainage technique naturally led to 'claying' where a layer of moist clay washed the molasses on the outside of the crystals into the drainage receptacle. This technique reached China via the agency of Muslim traders probably during the Yüan dynasty.

Sugar makers in India possessed a great store of empirical knowledge concerning crystallisation from the +1st century, well ahead of saltpetre (sodium nitrate) and common salt (sodium chloride) production. The primacy of sugar over saltpetre and salt as the medium by which man first described the process of crystallisation, also pertained in China for the new Indian sugar-making techniques were only introduced between the +7th and +9th centuries. The *Thang Shuang Phu* of c. +1154 demonstrated a clear practical knowledge of crystallisation, especially concerning the relationship between temperature and crystallisation.

The reboiling of sugar to make higher grades of sucrose first arose in the Islamic World about +1100, and was adopted in China during the +15th century. Sugar-manufacture technology, perhaps more than any other, demonstrated the oecumenical nature of technology. There were three waves of transfer: first, from India about +500 to Persia, and c. +650 and after to China, for crystallisation and drainage techniques; second, from the Islamic

[a] Subsiders first worked on exactly the same principle of syphoning off the clear juice in the middle, but recently, factories de-aerate juice before pumping it into a subsider, which precipitates all the impurities to the bottom and no scum rises to the surface. This allows juice to be drawn off from the top. The Chinese, of course, had no de-aeration technology.

World to Europe with indigenous and Chinese technologies such as the edge-runner and drainage cone about +900 to +1200; third, from China to the New World about +1600 to +1650 for the vertical, two-roller mill and the 'Jamaica train'. Of the Chinese contributions, the edge-runner had the greatest significance. It most probably originated in oil milling in China, and served as the major machine for crushing sugarcane from about +900 to +1500 over a wide area extending from China through to Spain and the New World. As one of the significant inventions of mankind, it was also applied to the processing of indigo, tea and other produce, as well as crushing ore, and eventually became known as the gunpowder mill. In the other major development on a world scale, rolling and roller-mill technology, which spanned the three occupations of cotton ginning, metal rolling and sugarcane crushing, the Chinese contribution remained confined to the vertical alignment of the rollers.

(*f*) TRANSFER OF CHINESE SUGAR-MAKING TECHNOLOGY TO EAST AND SOUTH-EAST ASIA[a]

In recent times concern with the transfer of Western technology to Third World countries seems to have diverted the attention of scholars away from the significant role played by technology transfer in the economic and social development of pre-modern Asia. In the following pages I will consider East and South-East Asia, demonstrating how individual States borrowed or received, a single agro-industrial sugar technology from China to aid their economic development.

As remarked earlier in (*b*), domestic sugar production in China began to increase from the +16th century and expanded greatly with the immigration of Fukienese peasants to Taiwan, Chiang-Hsi and Kuang-Tung during the +17th century. Individuals or groups of people with knowledge of, or access to, all the component elements of the technological package effected transfer and diffusion. Chinese immigrants took the package overseas from the late +16th century, and laid the technological foundations of pre-modern East and South-East Asian sugar production that lasted until the +20th century.

Though china enjoyed a good deal of technological interaction with neighbouring countries well before the +16th century, lack of source materials has hampered the demonstration of exactly how and under what conditions Chinese technology was actually transferred. We have considerable information about sugar, and as we shall presently see, it provides remarkable examples of full-scale technology transfer between Asian countries before the Industrial Revolution in Europe. But sugar was not the only Chinese technology taken to East and South-East Asia in this period of unprecedented economic growth, and before examining the individual cases of sugar technology transfer, we must gain some idea of the contemporary patterns and mediums of transfer.

[a] This is an expanded version of ideas first expounded in Christian Daniels (*5*) and (*6*).

(1) Patterns of Post +16th Century Technological Transfer in East and South-East Asia

China remained the most technologically advanced country in East and South-East Asia until the +16th and +17th centuries. No other country in the region possessed the technology and requisite business acumen to manufacture raw silk, silk textiles, porcelain, lacquer, tea and other trade commodities of such high quality on so great a scale. Foreign merchants, both Asian and European, flocked to China and their intense desire to trade for these commodities led them to resort to illegal transactions, if the volume passing through the normal channels of the tribute trading system proved inadequate. An overseas market for Chinese goods had existed from the +9th century at least, but the unprecedented post +16th-century expansion in demand for Chinese commodities, many agro-industrial, on the intra-Asian and European markets, encouraged the transfer of Chinese technology to East Asian and south-East Asian States.[a] In these countries production commenced with the most advanced Chinese technology available at the time.

Viewed with reference to the development of trade, the transfer of Chinese manufacturing technology between the +16th and +18th centuries fell into two broad patterns.

(1) Chinese merchants shifted their enterprises overseas for domestic political and economic reasons and at the same time transferred technology. This pattern probably derived from the policy adopted by Ming and Chhing courts towards foreign trade. With few exceptions, Ming Emperors strictly prohibited any private trading with foreigners outside the officially regulated tribute trade system. In addition, they forbade Chinese subjects from travelling overseas or emigrating outside the Empire. However, during the second half of the +16th century, the Ming gradually legalised foreign trade, as their prohibitions came to be increasingly ignored. The Manchu conquerors as part of their strategy to weaken the Southern Ming forces, especially the Chêng regime ensconced in their stronghold on Taiwan, placed a complete ban on all coastal trade, both domestic and foreign, between +1655 and +1684. They did not stop at that, and attempted to sever completely all contact with the enemy on Taiwan, particularly the transport of grain, by forcibly moving all residents living along the coasts of Chiang-Nan, Chekiang, Fukien and Kuang-Tung thirty *li*[1] inland. This was the infamous *chhien-chieh ling*[2] or forced evacuation order, and foreign trade and travel only recommenced on a permanent basis with its rescission in +1684. Trade subsequently continued without too much interference, except for short intermittent bans during the +18th century. Such strict limitations

[a] See Daniels (*6*).

[1] 里 [2] 遷界令

made export difficult, though not impossible,[a] prompting Chinese merchants to move production bases overseas to meet the unabated demand for their commodities, especially raw silks and silk textiles. For example, Chinese merchants actively encouraged the production of raw silk and silk textiles for export to the Japanese market in the two semi-independent Vietnamese States known to contemporary traders, as Tongking[1] and Quang-Nam[2], from the late +16th century. But demand on the Japanese market fell sharply after the rescission of the *chhien-chieh ling* in +1684, as poor quality Vietnamese silks could not compete with the fine quality products from the homeland.[b]

The advantages of low production costs also lured Chinese merchants to other lands. Abundant supplies of cheap, good quality teak timber, suitable for shipbuilding, attracted Fukienese merchants and their artisans to Siam in the +17th century. After constructing the vessels they sailed them back to China for sale. The Chinese shipbuilding enterprises in Siam continued until the early 19th centuries, and in the boom years of the early +18th century production costs only amounted to between one fifth to one tenth of those in China.[c] On occasion the Chinese undertook the agriculture and manufacture of goods not produced at home; in Siam they managed production of black pepper,[d] a plant not native to China, but one for which they quickly learned the requisite skills, applying their business management skills at the growing end, as well as in trade.

As can be seen from these examples, the measure of free trade allowed between China and foreign countries, the cost differentials within the Asian trading zone and the attitudes of local potentates all influenced the transfer of Chinese production technology to their agro-industrial activities in East and South-East Asian States. The growth of intra-Asian trade acted as a driving force behind the post +16th-century transfer of Chinese sugar technology; Chinese organised production of sugar and other articles of commerce in South-East Asian countries simply because they earned good money.

(2) Governments introduced advanced Chinese technology to promote import substitution, as part of measures to rectify an imbalance of foreign payments. Japan was the example *par excellence* of this pattern of transfer. From the +16th century, the Japanese began to import increasingly large quantities of foreign goods, such as high-quality raw silk and silk textiles, paying for them with silver specie. This was made possible by mining rich reserves of silver,

[a] Despite the *chhien-chieh ling* policy the Chêng regime, with its mastery of the sea, still managed to obtain silk textiles and other Chinese commodities from agents on the mainland coast and export them to Japan, see Jên Hung-Chang (*1*), pp. 100–7.

[b] Innes (1), pp. 189–91.

[c] Viraphol (1), pp. 24, 96, 173, 299–300.

[d] For Chinese cultivation of black pepper and marketing in Siam during the early 19th century, see Crawfurd (1), p. 423.

[1] 東京 [2] 廣南

and the mastery of Chinese and Korean assaying techniques. The Japanese acquired a taste for Chinese luxury goods, and increasing consumption of previously unknown foods such as imported sugar, changed their eating habits.[a] The problem was, for how long could they afford all of these imported luxuries? Copper became the major export after silver production dwindled in the mid +17th century, but its reserves were not unlimited either. In +1685, the Bakufu placed a ceiling on the annual volume of foreign trade conducted at Nagasaki, also limiting imports of *shira'ito*[1] or high-quality Chinese raw silk. The Japanese practised sericulture, but they lacked the skill to make *shira'ito*[1], so the weavers at Nishijin[2] in Kyoto depended on imported raw material for weaving high-quality silk textiles. The import restrictions, in effect, signalled the beginning of the struggle for achieving domestic production of *shira'ito*[1], but the Japanese did not attain self-sufficiency until the +1720s.[b] The transfer of Chinese sugar technology to Japan in the +18th century displayed a similar pattern taking as long as eighty years for complete acquisition. I will discuss the relationship between this long time-gap and the claustration policy later, and here only note in passing that it was the dependence of Japanese consumers on imports, that motivated technological borrowing. Though the Bakufu acted for different reasons than regimes in South-East Asia, the transfer of Chinese technology to all the countries derived from their associations with the growth of intra-Asian trade.

(2) The Bearers of Technological Transfer

In pre-industrial societies, migration of skilled artisans was the principal method of technology transfer. The economic historian of Europe, Carlo M. Cipolla, has demonstrated the exceptional difficulty of transferring technology in cases where the recipient only relied on the printed word or blueprints of machines: written aids merely represented knowledge of the technology, but were no substitute for practical instruction.[c] Technological transfer was best accomplished by artisans directly instructing local people, or local craftsmen studying abroad in another country. Cipolla illustrated the point by citing the long time required for the transfer of a water-powered machine for throwing silk from Italy to England. The *Nuovo Teatro di Machine et Edificii* (+1607) by Vittorio Zonca, containing an accurate engraving of this machine, was available in England at the Bodleian Library on open access shelves from +1620 at least, but the English only succeeded in setting up a mill a century later, in +1717, after John Lombe personally conducted two years of industrial espionage in

[a] Hamashita & Kawakatsu (1).
[b] Tashiro (1).
[c] Cipolla (5). The same argument is repeated in Cipolla (6), pp. 185–92.

[1] 白糸 [2] 西陣

Italy. Attracting migrant artisans proved the quickest way to acquire technology, and they often came because of dislocation due to economic, religious and political oppression and war. Conversely, they could be enticed by lucrative offers from merchants and political rulers, but it was not sufficient for foreign artisans to merely reside in a country. For their technology to be adopted and diffused the following conditions proved essential: (1) a viable economic base, (2) the existence of workmen capable of learning the technology and skills, and (3) special treatment for these technicians in regard to tax and status from the State, or at least a non-interference policy.

Cipolla's exposition allows us to draw a simple rule of thumb for evaluating the speed of technological transfer; the presence of skilled migrants enabled it to occur within a very short space of time, but their absence delayed it. In countries like Japan, which after the +17th century forbade entry to alien artisans, it required a relatively long time to master foreign technology since local craftsmen had to learn the new techniques themselves through painstaking trial and error.

When speaking of technology transfer one must draw a distinction between knowledge and skill. It was not enough for artisans simply to impart knowledge of a new machine or technique, they also had to train local people to operate it, ensure that they mastered the critical points of production, and could even repair and construct equipment themselves. Acquiring the skills of manipulating machines and mastery of techniques was essential for the diffusion of technology within a country. But political policy and social organisation influenced the reception introduced technology received in each country. In Japan for instance, the claustration policy forced the State actively to promote both the acquisition of the technology and skill of sugar making itself. In contrast, the continuous flow of Chinese immigrants to Java, Siam and Malaya provided the initial transfer as well as the skilled labour, because the Chinese manufactured the sugar themselves. As we shall see later, in the Philippines the Chinese transferred sugar technology and skills to the local people, while still retaining control over quality in their capacity as purchasers. In accordance with the scope of this study, I will only treat the transfer of sugar technology from China up to the point where it takes root in the countries of East and South-East Asia, and leave the question of the diffusion and spread of that technology within these countries to specialists.

There can be no doubt as to the vital role the Chinese played in the development of sugar production in South-East Asia. As early as 1856 John Crawfurd, the renowned scholar but poor diplomat for the British East India Company, proclaimed:[a]

The sugar-cane, in so far as native industry is concerned, is grown everywhere luxuriantly in the Indian Islands, in small patches near the dwellings of the inhabitants

[a] Crawfurd (3), p. 410.

where rich dressings are easily available, but nowhere as a branch of husbandry. It is grown, in fact, only to be used as a kind of sweet-meat to be masticated in its fresh state, and never for the production of sugar, an art which, there is every reason to conclude, was unknown to the natives until taught by the Chinese. To grow the cane profitably on a large scale as a branch of husbandry, for the manufacture of sugar, is quite another matter. In this view it can be produced only in rich volcanic or alluvial lands, such as exist in some provinces of China, in some parts of Java, in some of the Philippine Islands, in parts of Cochin-China, Siam, and the valley of the Ganges. Even in these, it is excluded from the perennially irrigated lands, on which it is more profitable to grow rice. In general it may be said that, for native use, sugar is only produced from the cane in countries where palms cease to be abundant, which is the case in every country of Asia without the Tropic ...

With respect to the Indian Islands, then, the conclusion we must come to is, that sugar made from the cane was wholly unknown to their inhabitants, until introduced by the Chinese, and not even by them until exercising their industry under the protection of European governments. Down to the present day they are the sole manufacturers, not only in the archipelago, but in the Philippines. Cochin-China, and Siam; the origin of this branch of industry in the last two named countries, or at least its revival, being an affair of our own times.

Indeed the Chinese did start sugar production in South-East Asia, but their success did not depend solely on protection afforded by European rulers as Crawfurd claimed. As we shall presently see, the Chinese manufactured sugar just as well in areas controlled by indigenous potentates as in those under European domination. Moreover neither European nor local rulers were always as kind to the Chinese as our author suggested. The Spanish and Dutch periodically persecuted them, and occasionally extreme jealousy of Chinese industry and success drove them to massacre large numbers. Vietnamese and Siamese kings placed restrictions on the activities of Chinese residing within their realms. Crawfurd noted the place of palm sugar, but remained ignorant of the role of sugar made from sugarcane; the other major sugar in the lives of the indigenous people in Indochina prior to the coming of the Chinese. But no matter, whether from the sugar palm or sugar cane, the sugar produced never came to anything more than amorphous sugar (*shih-mi*[1]).[a] It is evident that after the +16th century the Chinese brought the method of manufacturing crystal sugar, *sha-thang*[2] and *pai-thang*[3] or clayed white sugar and, as we shall presently see, they aimed for the export market, and not local consumption.

Transfer basically falls into two types: one by recipient countries eager to acquire the technology for their own purposes, and the other by Chinese immigrants bent on making sugar to sell on the growing intra-Asian market. In accordance with the general pattern of the transfer of Chinese manufacturing

[a] See Gopal (1), pp. 68–72 for a discussion of the priority of sugar making from sugarcane over that from sugar palms in India. Gopal favoured the priority of sugarcane.

[1] 石蜜 [2] 沙糖 [3] 白糖

technology abroad, and the theory outlined above, we provide the following historical schema for sugar technology based on the presence of the Chinese double-roller sugar mill (documentation will appear later, unless noted otherwise).

A *Trade-induced transfer by Chinese immigrants* (transfer immediate, and production able to adjust quickly to market changes):

1 *The Philippines*: late +16th century by Fukienese immigrants
2 *Vietnam*: +17th century by Chinese immigrants
3 *The Indonesian Archipelago*: +17th century by Chinese immigrants
4 *Siam*: +17th century by Chinese immigrants, but discontinued in +18th century, and re-introduced by Chinese immigrants during the early +19th century
5 *The Malay Peninsula*: early +19th century by Chinese immigrants[a]
6 *Burma*: early +19th century by Chinese immigrants[b]
7 *Hawaii*: early +19th century by Chinese immigrants.[c]

Some of these countries had a strong tradition of consuming sugarcane before the arrival of the Chinese which may have influenced the following sub-pattern:

I *Transfer to local people*; local people in the Philippines and Vietnam undertook the sugarcane growing and sugar making.
II *Minimal transfer to local people*; Chinese immigrants undertook both the agriculture and manufacture in Siam, the Indonesian archipelago, and the Malay peninsula. By controlling all aspects of the production the Chinese were able to exercise quality control.

B *State-induced transfer*:

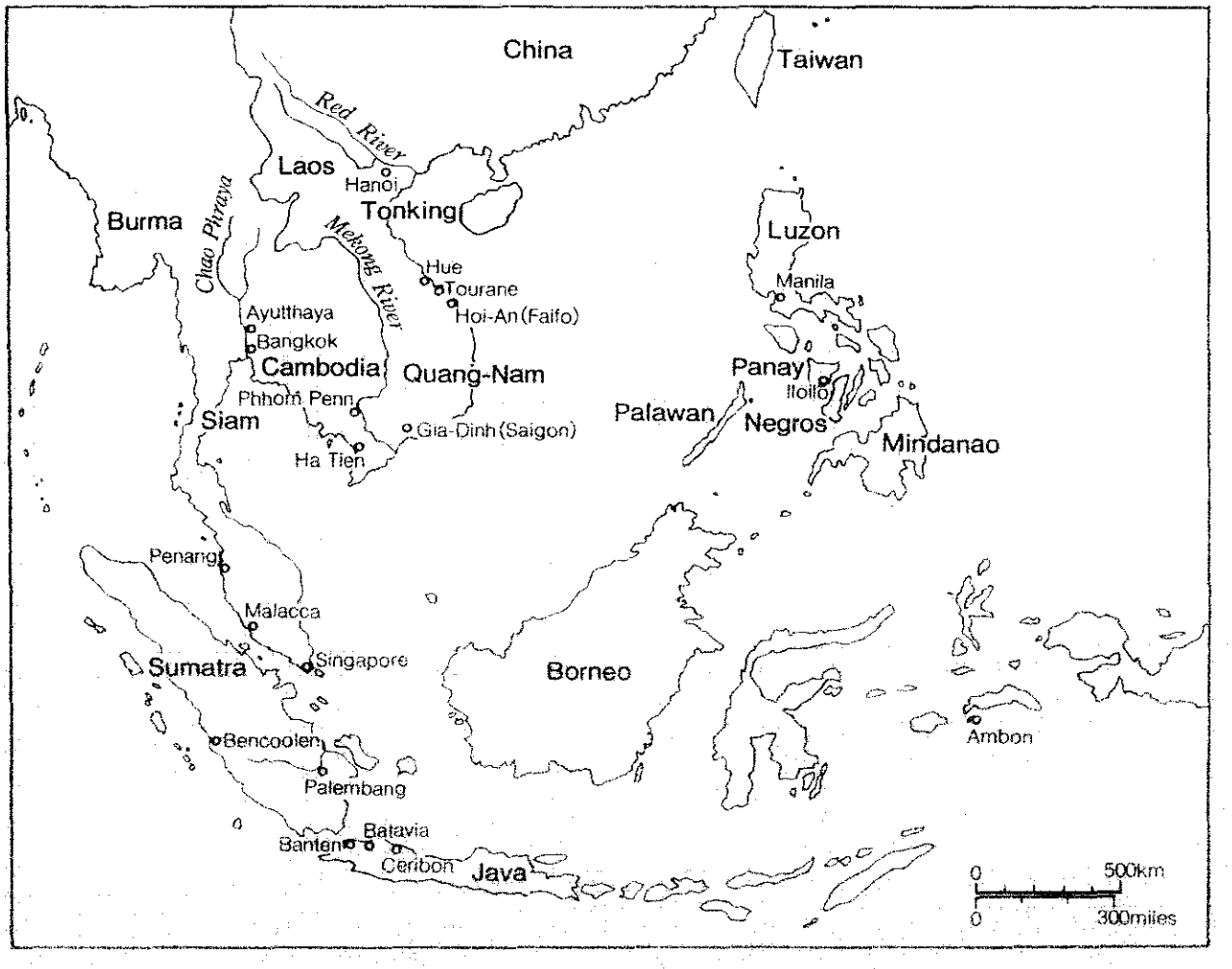
1 *The Ryūkyū Kingdom*: in +1623, acquired directly from China by despatching people to learn technology in Fukien; motive, revenue earner
2 *The Amami Islands*: late +17th century, acquired from Ryūkyū Islands; motive, revenue earner

[a] See Wray (1), pp. 124ff for Province Wellesley and Tan (1).

[b] Watt ((1), Vol. 6, pt 2, pp. 248–9) and Barber ((6), p. 395) recorded the two-roller mill in +19th-century Burma. In fact some of the best information we have on the rates and efficiencies of the Chinese mill come from this country. Information is scarce, and we are left in the dark as to how or when Chinese sugar technology was transferred. Watt described the involvement of the Chinese in Burmese sugar production as moneylenders, which means that they may have introduced the mills to protect their investment or simply for profit.

[c] The Chinese double-roller mill was used to make sugar before +1852, when plantations in Hawaii introduced steam-driven iron roller mills. Chinese stores in Hawaii brought sugar masters (*thang shih*[1]) there to work under the credit ticket system. It is not exactly clear when Chinese sugar masters first arrived in Hawaii, but we do know that in 1802 a Chinese made sugar there before leaving the following year, see Cushing (1). See Kai (1) for accounts of subsequent Chinese sugar masters who immigrated and settled in Hawaii before 1852.

[1] 糖師



Map 4. Places related to the transfer of Chinese sugar technology in South-East Asia, +17th to +19th centuries.

3 *Japan*: +1726 to c. 1800. A long time was required to master and spread the technology due to the prohibition on Chinese or any other artisans entering the country. Motive was import substitution; sugarcane and sugar were new commodities in Japan, imported in increasingly large volumes after the +16th century.

The Chinese carried their sugar technology with them to most of the countries to which they immigrated after the +16th century, even extending out in the Pacific to Hawaii, and to Burma on the verge of South and South-East Asia. Unfortunately due to limitations of space I am not able to examine the history of sugar technology in all of the countries, but only to study the transfer of Chinese technology to four from the former group and the three from the latter.

(3) Case Studies of Trade-induced Transfer by Chinese Immigrants

(i) *The Philippines*

According to Wang Ta-Yüan[1], the Chinese traveller who visited the Philippines sometime during the +1330s and +1340s, the inhabitants, 'brewed sugarcane syrup to make wine' at a subsistence level before European contact.[a] Though Chinese immigrants introduced the same sugar technology that was later documented in the *Thien Kung Khai Wu* in the late +16th century, making the Philippines the first country in South-East Asia to receive it, it did not take root among the Filipinos until nearly two hundred years later. Chinese technology only became the mainstay of production after its diffusion in the late +18th century, and plantation owners in the 19th century adapted it to manufacture an array of sugars, even substitutes for centrifugal sugars.

For making wine not sugar

The earliest known reference to a double-roller vertical sugar mill anywhere in the world appeared in an early Spanish-Tagalog vocabulary, *Vocabulario De Lengua Tagala* of +1613 by Father Fray Pedro de San Buenaventura. In view of its significance I cite it in full:[b]

Alilisan: Sugarcane Press; they are two poles (*palo*), the one is fixed and the other goes up and down, and they press the canes there between them; there is another one of the same name, which is from the Sangleys [Chinese], which the Indios now use, which

[a] *Tao I Chih Lüeh*, pp. 23 and 89.

[b] Buenaventura (1), p. 420. Translation kindly furnished by William Henry Scott of Mountain Province, the Philippines.

[1] 汪大淵

works like a *noria* [lit. chain-pump, draw-well]; it's two logs (*palo*) both toothed together so that one fits solidly into the other.[a]

An introduction in the late +16th century must have occurred for the two-roller vertical mill to have been adopted by the Filipinos for description here. This reference predated the *Thien Kung Khai Wu* of +1637, the first source in China, and the significant point is that Buenaventura specifically stated its Chinese provenance, which confirmed the presence of the roller mill in the homeland during the latter half of the +16th century, at least.

Large numbers of Chinese, the agents of transfer, resided in Manila during the late +16th century. In fact, the Chinese population of the city swelled dramatically from 150 in +1571 to 24,000 in +1592, after which the authorities started to repatriate large numbers to China.[b] The Chinese do not seem to have manufactured much sugar at Manila, for merchants imported large quantities from China after +1572,[c] but a transfer must have been affected by the time of Buenaventura. With sugarcane and sugarcane wine as indigenous foods the Filipinos undoubtedly displayed interest in the new technology.[d]

The Jesuit Francisco Alcina, in his +1668 MS 'Historia de las islas e indios de Bisaya', pointed out that Filipinos, mostly subsistence agriculturalists, employed the Chinese double-roller sugar mill solely to extract the juice from sugarcane to brew wine,[e] but not for making sugar for export as did the Chinese in Java and Siam. In fact William Henry Scott, a leading authority on +16th- and +17th-century Filipino history, informed me that he knows of no +16th-century European observer who speaks of sugar in the Philippines, nor of any early Spanish dictionary which recorded any native word for sugar, though there are many for sugarcane and sugarcane wine. There is apparently no indigenous term for sugar in modern Philippine languages, all of which say

[a] It is obvious from the evidence in Spanish dictionaries that the term *noria* referred to an animal-driven chain-pump in the Philippines. My correspondent, William Henry Scott, in a private communication of January 1990 informed me that all the Spanish dictionaries available to him described the *noria* as a machine with two wheels, a horizontal one turned by a draft animal and a vertical one to lift water, not from a flowing stream but from a pond also called a *noria*. As such, in this context, *noria* means a machine activated by a whim which animals powered by walking around in a circle. A two-roller vertical sugar mill has the same arrangement. The terminology of waterlifting machinery is obscure, but in the terminology used in *Science and Civilisation in China* the one described here was a *sāqīya*, see Vol. 4, pt 2, p. 331, fn. b. The fact that Buenaventura said the two logs (rollers) were geared together by teeth in the rollers, indicated that the machine was a two roller vertical mill. The only known design of a horizontal mill with *sāqīya* gearing has teethed wheels attached to the end of each roller (see Fig. 77).

[b] Ch'en Ching-Ho (1), p. 32. *Ibid.*, p. 148 reported that half of the 24,000 Chinese were repatriated between +1592 and +1597.

[c] *Ibid.*, pp. 33, 64, 77 and 114.

[d] The mid 14th-century Chinese visitor to the Philippines, Wang Ta-Yüan noticed the making of sugarcane wine in his *Tao I Chih Lüeh*, pp. 23 and 89, and Antonio Pigafetta recorded that the Spanish demanded sugarcane from the Palawan governor, so we may assume widespread consumption, see Paige (1), pp. 82, 85, 87, 89.

[e] Alcina (1), I: 1;29. Once again I am grateful to William Henry Scott for this source. Sonza ((1, p. 2) stated that the Philippine sugar industry commenced with equipment consisting of a wooden lever press for expressing the juice and pottery cauldrons for boiling the juice into hard cakes. This was undoubtedly the method of manufacture by Filipinos for boiling sugarcane wine before the advent of Chinese technology.

asokar, from the Spanish.[a] Visayan and Bikol dictionaries of the early +17th century, recorded other lever-type presses without any mention of the double-roller vertical mill, so we can see that it had not achieved a predominant position amongst all Filipino ethnic groups.[b] Even today the simple lever mill is still used on the Cordillera in northern Luzon, but always for making wine, and never for manufacturing sugar.[c] The Filipinos probably came into contact with the whole *Thien Kung Khai Wu* sugar-making package, but some of them only selected the roller mill to replace their more cumbersome lever-type presses; not being accustomed to consuming sugar they had no need for sugar-making technology, and only adopted the new crushing equipment because it increased the efficiency of juice extraction for making their traditional beverage, sugarcane wine.[d] The rapidity of its spread to some sections of the local community constituted a rather rare case in the history of the transfer of post +16th-century Chinese sugar technology to South-East Asia.

Apathy of the Spanish administration

Contrary to popular belief, sugar production for the overseas market preceded the late +18th century. This is shown first by instructions issued by the rectors of the College of San José of Manila to the Jesuit lay-brothers, who managed the college estates in the +17th century, and second by sources for +1640 and +1685, which recorded sugar available for export.[e] It is not surprising that little is known about these operations as the Jesuits had to keep as low a profile as possible, having received severe criticism for their financial dealings in East Asia in general,[f] and in the Philippines in particular.[g] We now have to examine

[a] Private communication, January 1990. I do not claim competence in the linguistic problems surrounding early European texts on the Philippines, but would point out that the Paige translation of Pigafetta definitely mentioned sugars, see Paige (1), p. 82.

[b] I am grateful to William Henry Scott for this information. Sonza ((1), p. 2) described an apparatus which crushed the sugarcane on a wooden surface with a hand- or foot-operated lever, the juice dropping through a sluice into a container, also see photograph in Hines (2), p. 302. A mill using the same principle has been photographed in Indo-China, but in this case the lever crushed the cane in a tree fork, see Sarraut (1), p. 357.

[c] William Henry Scott, private communication of January 1990.

[d] *Ibid.*; Scott reported that this sugarcane wine is still consumed under the name of *fasi/basi* in various parts of the Philippines. Apparently it appears bottled on shelves in Manila supermarkets as *Damo Basi* (i.e. manufactured by Mr Damo), and William Dampier gave the name Bashee Island to the one where he found this beverage in plenty and quality in +1687.

[e] Costa (1), pp. 115–16; Sonza (1), p. 3.

[f] Boxer (7), pp. 120–1.

[g] Cushner (2), p. 98. The question of why the clergy failed to respond by manufacturing large quantities of sugar is more difficult. I believe that there were three major factors. First, the Jesuits, the major entrepreneurs, along with other orders came under fire for their involvement in the affairs of the world, such as in Galleon trading and usurping land, see Cushner (2), p. 98. They needed to keep as low a profile as possible unless there was a potential for great gains. Second, there were the problems of markets. Trade was restricted to Peru and Mexico by the Manila Galleon, the only authorised outlet in that direction, and in any case Peru and Mexico were self-sufficient and exporters of sugar. There was a sugar market in China, and undoubtedly small clandestine trade with that country, but large political obstacles existed on both sides for this to become official. Third, the first Bishop of the Philippines, Fray Domingo de Salazar, a colleague of Las Casas, early established a high moral stance against the exploitation of the indigenous people, which enjoyed regal back-

(*cont.*)

why this incipient sugar production of the +17th century failed to develop prior to the late +18th century. Why did the Chinese, who had the expertise, not come to the fore as they did in Java?

The answer lies in the general Spanish policy towards the Philippines. First, prior to the mid +18th century the Spanish displayed little interest in developing the resources of the archipelago, preferring to keep the colony as an entrepôt for the trade between China and Spanish America. Until the late +18th century economic activities concentrated on supplying the Manila Galleon with Chinese goods, especially the much coveted silk.[a] The Spanish *encomenderos* lacked capital and found it difficult to collect tribute from the Filipinos,[b] who living as subsistence agriculturalists, produced little for the market and proved unsatisfactory sources of labour. The *encomenderos* found it difficult to survive as they failed to attain an economic base in the land, and only achieved economic viability by participating in the Manila Galleon trade.[c] Second, came the insistence on strictly limiting the activities of the Chinese. Administrators and settlers in Manila, ever envious and suspicious of Chinese business acumen and industriousness, repressed them, even persecuted them as pagans, whenever the Chinese overstepped an invisible line arbitrarily drawn by the Spanish. Despite massacres, as in +1603 and +1639,[d] imposition of poll taxes and orders of deportation, the Spanish could never really do without all of them as Chinese artisans and workmen provided most of the essential services of the colonial outpost. About +1680 Governor Vargas Hurtado ordered all the Chinese living in the provinces to reside in the Parián,[e] the Chinese quarter outside the walls of Manila. This precluded them from obtaining land in the countryside to grow sugarcane and manufacture sugar as their compatriots did in Java in the +17th and +18th centuries. The Chinese only obtained freedom to travel the countryside to encourage Filipinos to grow sugarcane after the late +18th century when the Spanish relaxed restrictions.

Footnotes to page 421 (*cont.*)

ing. The Church in the Philippines exhibited more interest in saving souls than pursuing economic gain. In this respect, the Church and government had gained a lot of experience in handling souls in the New World. For a very perceptive essay on this subject and the relationship of Church and State see Costa (1), pp. 22–38. The heavy involvement of the Church in labour relations continued into the 19th century. While the Church did not officially exploit the indigenes they continued to acquire ownership of land by 'royal grant, legacy or outright purchase'. When sugar production grew in the 19th century, the Church Orders were the major landowners (haciendas), and they subleased holdings to Chinese *mestizos* (part Chinese) or natives, collectively known as *inquilinos* who ran them as sub haciendas employing labour known as *kasamahanes*, see Cushner (2), pp. 212–13 for a summary of the relationships and methods of working.

[a] Costa (1), p. 19.

[b] The Spanish implemented an *encomienda* system in the Philippines modelled on their Caribbean possessions. *Encomenderos* had the right to collect tribute from people in certain areas, with the corresponding responsibility of providing protection and spiritual administration, see Cushner (1), p. 265.

[c] Costa (1), p. 19.

[d] Fischer (1), p. 702.

[e] Cushner (2), p. 167.

Adaptation of Chinese sugar technology to the plantation system

In +1778 Don José Basco y Vargas Valderrama y Rivera, a *prodigé* of the Spanish Bourbon reformers, assumed office as governor of the Philippines, beginning immediately to stimulate agriculture and trade. He published his 'General Development Plan' soon after arrival in +1779, and offered incentives for agriculture and to this end circulated instructions concerning the latest methods of cotton cultivation, sericulture and sugar production.[a] He founded the *Sociedad Económica de Amigos del Pais* (Economic Society of the Friends of the Country) in +1781 to promote research and development in primary products, and in +1785 the *Real Compania de Filipinas* (Royal Philippine Company) to engage actively in trade with Spain.[b] During the +1780s the *Sociedad Económica* even went to the trouble of bringing sericultural experts out from China (most of them professed Christians of course) in an abortive attempt to transplant silk-raising technology to the colony.[c] Later governors achieved success with this policy of encouraging agro-industrial development in the archipelago, and increased the export of sugar, indigo, tobacco and other produce during the 19th century.

The Chinese, with their affiliates in all the major sugar-making areas, filled the demand and immediately organised an exceptionally efficient system of sugar production, so efficient in fact that the amount of sugar exported between +1785 and 1854 rose from a minimal amount to 762,643 piculs (45,758 tonnes).[d] In order to refine sugar for export, the Chinese, or rather the *mestizo* (offspring of intermarriage between Chinese and Filipino women) and their agents, travelled the provinces buying muscovado which they packed in *pilones*, large conical earthenware jars weighing one picul (approx. 60 kilos) for transport to the capital. The crushing technology employed by the Filipino sugarcane growers as well as the claying techniques of the Chinese in Manila greatly resembled those outlined in the *Thien Kung Khai Wu* of +1637 as the observations of Robert Mac Micking in the late 1840s testified:[e]

> The mills employed for expressing the juice from the cane are nearly all of stone; and firewood is usually employed to boil the sugar; for although they have for some years introduced the plan of employing the refuse of the cane for that purpose, it is not yet very general ...
>
> When enough [muscovado sugar] has been collected [by the Chinese or their agents]

[a] Cushner (2), pp. 188 and 194.

[b] Costa (1), p. 130; Cushner (1), pp. 186, 188, 190, 194.

[c] See Sugaya (1), pp. 58–64.

[d] Cushner (2), p. 201. Costa (1), p. 135–6 has summarised the role of the Chinese in the development of sugar production in the following terms: 'The privileged position accorded the Chinese by Spanish policy was immensely strengthened by the British, French and American import-export houses that established themselves in Manila after the opening of the Philippines to world trade. These firms found in the principal Chinese merchant families, with their affiliates in practically every town of consequence in the archipelago, a ready-made marketing system and quite naturally channeled their business almost exclusively through them.'

[e] Mac Micking (1), pp. 281–3.

in one neighbourhood to load a casco or other province boat, it is despatched to their camarine at Manila, where after being taken from the original *pilone*, if it has come from Pampanga, it is mixed up together, and placed in another one, with an opening at the conical part, which is placed over a jar into which the molasses distilling from it gradually drop, when the colour of the sugar from being brown becomes of a greyish tinge.

At the top of the *pilone*, so placed with the cone turned down, a layer of clay is spread over the sugar, as it has the property of attracting all the impurities to itself; so that the parts of the sugar in the *pilone* next to the clay are certain to be of the whitest and best colour, whilst the sugar at the bottom, or next the opening of the cone, is the darkest and most valueless, until it has had its turn of the clay; for when the Chinamen perceive that the top part of the sugar in the *pilone* or earthen jar has attained a certain degree of whiteness, they separate the white from the darker coloured, and the greyish tinged sugar from the dark brown coloured portion at the foot of the jar; and after exposing the white and greyish coloured to the sun, they are packed up, while the dark brown portion after being mixed with that of a similar colour, is again consigned to the *pilone* to be clayed.

It seems as though the Chinese re-introduced many components of the *Thien Kung Khai Wu* technology during the +19th century to boost production levels. Though stone rollers appeared in China during the +17th century, if not earlier, they only arrived in the Philippines in the early 19th century according to Sonza;[a] they may have been introduced at the time of initial transfer, but not adopted as Filipinos had greater access to wood than stone. Abundant supplies of wood delayed the use of cane refuse as fuel for the boiling pans. Sonza reported that the Chinese replaced pottery pans previously used for boiling the expressed juice with iron cauldrons called *kawa* at the same time.[b]

The sugar technology adopted in the Philippines after the early 19th century aimed to manufacture high-grade sugar for export to American, Chinese and English merchants. Two distinct types of technology emerged (*1*) the draining of massecuite in cones, and (*2*) the *sha-thang* beating method. Both techniques seem to have been implemented in different parts of the Philippines to suit variant systems of production.

Draining massecuite in cones

After heaving up to strike point, the syrup was poured directly into *pilones*,[c] and then stirred to promote crystallisation. Workmen set the *pilones* over smaller jars of about one-and-one-half gallon capacity, freed the bottom plugs and left the molasses to drain. This was a quick method of obtaining a massecuite, conducted mostly in areas where the Chinese bought massecuite from the

[a] Sonza (1), p. 4. For stone rollers in China see (*e*), above.

[b] *Ibid.*

[c] Hines (2), p. 300, described the *pilone*: 'This is a bell-shaped earthen jar varying in capacity from 130 to 180 pounds of crude sugar. It is about two feet in height and one and one half feet in diameter at the top. In the bottom of each of these jars is a hole about two inches in diameter, through which the molasses drains. When the sugar is placed in these containers a few pieces of bagasse or some clay is first placed in the bottom to prevent the heavy sugar solution from passing through and being lost.'

indigenous peoples and the *mestizos*. The completion of the crystallisation and draining process in a *pilone* provided a convenient utensil for transportation; the jars facilitating the easy collection and transport of massecuite from large numbers of small producers scattered over a wide area to refineries located in Manila. At Manila the *pilones* were either broken up and the sugar dried, graded and rebagged, or set over smaller jars of about one-and-one-half gallon capacity. In the case of the latter, operators pasted about two inches of clay on top of the sugar and kept it continuously moist. They removed the sugar from the *pilones* after several months, divided it into grades, pulverised and dried it in the sun and then bagged it for export.[a]

The Chinese also manufactured caramelo sugar, which from an existing description, resembled the honey pieces (*mi-phiên*[1]) or slab sugar (*phiên-thang*[2]) of China:[b]

The manufacture of this semi-refined sugar for local consumption is an industry conducted exclusively by the Chinese both here and on the China coast. The upper portion of the pilon sugar which is the lightest and whitest is dissolved clarified by a mixture of albumin of eggs and lime and boiled to the crystallization point in shallow, copper pans in which it is stirred vigorously until the mass is light and porous and crystallization is complete. It is then cut into blocks about one and one-half inch by one-half inch and packed away in large earthen jars, ready for market.

The sha-thang *beating method*

The *sha-thang* beating method emerged on the island of Panay and Negros in the Visayas, which became the premier sugar region of the archipelago after c. 1850. The island of Negros had seven small sugar mills before 1849, when the Rocolto order began sugar production under government decree. They subdivided the land, which was brought under cultivation to a large extent by *mestizos* from Panay, and later some Spanish by 1857.[c] What concerns us here is that plantations both large and small employed the same technology. The author of a United States Consular Report for the late 1880s, though blinded by concern for massecuite sugars with high nett titre for refining in modern factories, still retained the presence of mind to see the efficiency and simplicity of the technology:[d]

But the system followed in Iloilo [Panay] is far more profitable and satisfactory generally than that of manufacturing sugar in pilons, or by the barbarous system pursued by the people of Taal [on Luzon]. It does not require more machinery or apparatus than

[a] Hines (2), p. 300 gave a photograph of a large storehouse.

[b] Hines (1), p. 239.

[c] When the Americans assumed control of the Philippines they found it difficult to ascertain the truth about the development of Negros despite two commissions of inquiry, see Walker, H. S. (1), p. 1. The Spanish claimed that they did it all, see Locsin (1), and others wrote as if local people including the *mestizos* did the job, see Costa (1), p. 76. The truth probably lies somewhere in between.

[d] United States Consul (1), p. 76.

[1] 蜜片 [2] 片糖

the others, but it is characterised by greater care, cleanliness, and accuracy in the process of manufacture. The juice is boiled until it arrives at a certain density, only to be judged by an experienced boiler, and it is then emptied into wooden troughs or trays in thin layers and beaten until it assumes a yellow colour, and becomes an amorphous sugar, known as 'Superior de Iloilo'. It is put in bags for sale immediately, and is ready for exportation without any preparation. It does not drip molasses, and its loss in weight is insignificant. Besides, the planter obtains for his superior sugar a price equal to that obtained by the farderos [drying and repacking institutions] for their best Manila sugars.

The resulting product went under the name, *bayong* or mat sugar,[a] the technology being the same beating technique as that transferred from India to China during the Thang dynasty. The beaten sugar, dried by the heat of crystallisation, was a very popular technique on the south-east China littoral during the 19th century. What is of great interest to us is that planters applied the same Chinese methods on plantations producing about 20 to 400 tonnes of sugar all of export quality[b] (see Fig. 113). I suggest that the technology was a scaled-up version of the Chinese methods practised by *mestizos*, milling rates being increased by simply introducing water- and steam-powered mills, and providing larger tanks and open pan boiling units. In the largest-scale operations workers poured the heavy syrup onto large concrete slabs and then 'beat' it by turning over with shovels.[c]

The large *mestizo* population, as well as the efforts of full-blood Chinese, enacted the transfer of the requisite techniques. The *mestizos* found acceptance in the Philippines because most of them embraced the Catholic religion, and became acculturated with Filipino society. They eventually formed an economic and intellectual elite, which gave birth to the hero of the revolution against Spanish rule, the *mestizo*, José Rizal y Mercado. The *mestizos* and Chinese displayed great versatility in adjusting their technology to meet the different economic and social conditions within the archipelago. On the one hand, *mestizos* travelling the countryside to buy sugar from the early 19th century exercised a certain amount of quality control over Filipino producers on Luzon[d] by virtue of being the manufacturers of white sugar, and ordering production of a particular quality of muscovado. On the other hand, on Panay and Negros, the shortage of indigenous agriculturalists forced the *mestizos* to adapt Chinese sugar technology to larger, plantation-scale operations.

[a] Hines (1), p. 239 also described the process for making *bayong* or mat sugar.

[b] In 1849 at the commencement of production on Negros, seven wooden mills made 190 tons of sugar, averaging about 27 tons per mill, see Walker, H. S. (1), p. 1. After the post-1849 expansion with the emergence of large haciendas that could produce about 400 tons of sugar (see Lotsin (1), p. 44), there were still a large number of small mills (500 in 1880 according to Walker, H. S. (1), p. 16) some of which must have operated at about the level of the old wooden mills of 1849. According to United States Consul (1), pp. 75–6 the methods outlined for Negros were identical with those used throughout the whole of the Visaya group.

[c] See figure in Prinsen Geerligs (1), p. 100.

[d] Blanco ((1), pp. 42–4), writing in 1837, stated that Filipinos undertook sugarcane cultivation and sugar making, though the methods employed were patently Chinese.

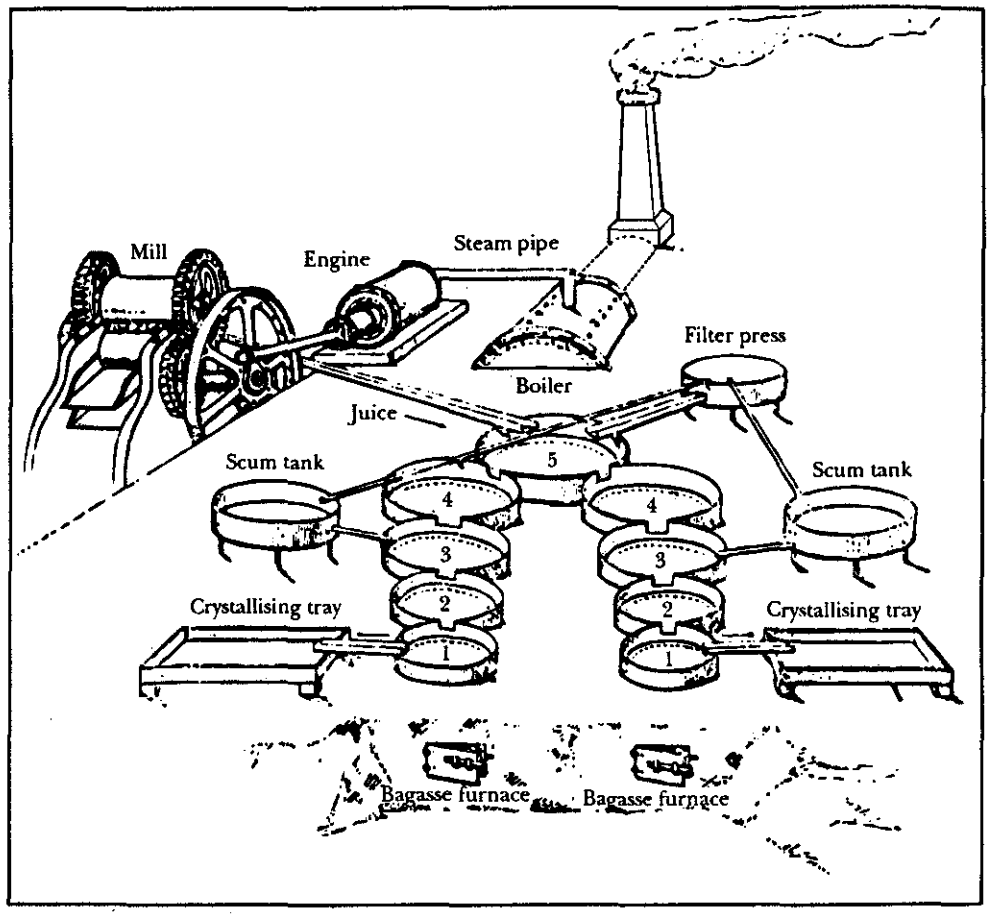


Fig. 113. A diagrammatic representation of a sugar mill on Negros, the Philippines, during the 19th century. It is a good example of how traditional Chinese technology was adapted to steam. Two furnaces heated two batteries of open pans producing the steam to drive a three-roller horizontal mill. The juice was limed and pre-heated in a common pan, the *cava*, from which it was distributed to the two trains of pans. Scum was skimmed from the second boiling pan, and directed into the scum tank, from which some juice was syphoned back for boiling and the remainder sent to a filter press for treatment and returning to the *cava*. When the syrup reached the right consistency in the final pans, it was run into the crystallising trays, where it was stirred and shovelled with spades to make *sha-thang* for immediate bagging and marketing; Prinsen Geerligs (1), p. 100.

(ii) *Vietnam*

Before treating the question of transfer to Vietnam I must devote a few explanatory words to the history of the country after the +16th century. Designations by both Chinese and Europeans for the geographical area now known as Vietnam have changed with time. The Han Emperors initially used the term *Chiao-Chih*[1] as a general designation of the area in these parts where they established administrative organs, but from the late +12th century the term An-

[1] 交趾 or 交阯

Nan[1] or Pacified South came into use. The Vietnamese preferred Dai-Viêt[2], that is the Great (country) of the Viêt, which seems to be their oldest ethnic name.[a] The Vietnamese have over the centuries continually expanded in a southerly direction, only reaching the Mekong delta in the +17th century. Some European authors have used Tongking[3] for the Red River basin in the north, Annam for central Vietnam and Cochin-China for the south. But this historical usage has not always been consistent, and to avoid confusion I use the geographical terms, Tongking, central Vietnam and south Vietnam; the latter two being the areas where sugar production expanded most.

Historical background and immigration of Chinese

Vietnam with it's capital city, *Thăng-long*[4] or Rising Dragon, located at Hanoi[5], remained nominally united under the latter Lê[6] dynasty (+1428 to +1789) in the period under consideration. However, after +1620, the administration and control of the country fell into the hands of two rival factions led by the Trịnh[7] and Nguyên[8] families, who ruled *de facto* as almost independent states, over the Tongking area in the north, and central Vietnam in the south respectively.[b] Though Chinese immigrants from south China poured into both the north and south in large numbers after the turmoil accompanying the fall of the Ming, the Trịnh and Nguyên regimes adopted markedly different policies towards them.

In contrast to a generally repressive stance taken by the Trịnh,[c] the Nguyên used the Chinese immigrants to their advantage in their struggle to resist the constant military threat from their northern arch enemies. The Nguyên implemented two positive measures to strengthen the economic base of their regime, known to the Chinese as the Quang-Nam kingdom[9]. First, they expanded their land base by encroaching upon the territory of Champa[10], a former glorious State now reduced to living within the confines of present-day South Vietnam; the Nguyên all the time encouraged the development of virgin land for cultivation. Second, they promoted foreign trade by opening the two central Vietnamese ports of Hôi-An[11] (Faifo) and Tourane[12] to Chinese, Japanese, European and

[a] Gia-Long[13], the first Emperor of the Nguyên dynasty proclaimed the designation Viêt-Nam[14] or Yüeh-Nan in 1803, see Brodrick (1), p. 149.

[b] Of course apart from the Trịnh in the north, the Mac[15] family controlled Cao-Bang[16] near the Chinese border, but the Trịnh conquered them in +1677.

[c] From the early +18th century large numbers of single Chinese males flowed into the Tongking area to work in the mines. In order to check the consequent disruption they caused to Tongking society, the Trịnh adopted a generally repressive policy, placing restrictions on their places of residence, see Fujiwara (*1*), pp. 236–56.

[1] 安南 [2] 大越 [3] 東京 [4] 昇隆 or 昇龍 [5] 河內
[6] 黎朝 [7] 鄭氏 [8] 阮氏 [9] 廣南國 [10] 占城
[11] 會安 [12] 沱濃 [13] 嘉隆 [14] 越南 [15] 莫氏
[16] 高平

other merchants. The Chinese played a large role in both of these endeavours.

The Nguyên immediately put the Chinese immigrants to work clearing land, which, of course, ultimately increased the fiscal income of their regime. According to the *Đại Nam Thực Lục*[1] (Veritable Records of the Great Viêt), the Ming generals Yang Yen-Ti[2] and Chhen Shang-Chhuan[3],[a] arrived in Quang-Nam in +1679 with three thousand soldiers in fifty warships and swore allegiance to the Nguyên,[b] who promptly despatched them to open up frontier land controlled by the Champa state; their presence presumably attracted more Chinese labour to join them in the task.[c] By the +1690s all the Chinese in Quang-Nam, including the merchants, were settled residents integrated administratively into Vietnamese society through registration in the communities of *minh-hu'ong xa*[4] and *thanh hà xa*[5]. Much of the land opened up by the Chinese lay in Gia-Dinh[6] province, the region around present-day Saigon or Ho Chi Min city. Since this became a major sugar-producing area during the +18th and 19th centuries,[d] we may safely assume that Chinese sugar technology arrived here sometime during the +17th century. It is also notable that the two large sugar-producing regions of Vietnam in the late +18th and 19th centuries, Quang-Nam[7] and Quang-Ngai[8] provinces,[e] lay within Nguyên territory where Chinese were encouraged to engage in agriculture and trade.

The Chinese made great contributions to the development of overseas trade in central and south Vietnam, in their capacity as semi-political leaders as well as traders. A Chinese leader, Mac Curu[9] (d. +1735), a native of Lei-Chou[10] in southern Kuang-Tung province, created his own semi-independent port city State in south Vietnam called Ha Tiên[11], and variously known in Chinese sources as Kang-Khou Kuo[12] and Pên-Ti Kuo[13]. Ha Tiên[f] originally belonged to the Cambodian King who appointed Mac Curu as governor of the region in the late +17th century, but in +1708 Mac swore allegiance to the Nguyên,

[a] Regional Commander of Lung-Mên[14] and Regional Commander of Kao-Chou Lei-Chou and Lien-Chou[15] in Kuang-Tung respectively.

[b] *Đại Nam Thực Lục, chinh biên*, 5, pp. 22a–23a, vol. 1, p. 82. Fujiwara (*1*), pp. 193 and 205–6, fn. 6 cited other Vietnamese sources supporting this claim. Fujiwara ((*1*), p. 193) suggested that these Ming generals were most probably Chinese pirates resisting the Chhing takeover. In any case, the Nguyên, who had been constantly at war with their northern enemies from +1627 to +1674, were in no position to refuse their help, and indeed immediately set them to work extending the southern limits of their territory.

[c] Fujiwara (*1*), pp. 192–6.

[d] Crawfurd ((1), p. 512), writing of the first half of the 1820s, estimated that roughly 30 junks plied between Saigon and ports in China each year and listed sugar as one of the principal exports. Edward Brown, who was detained in Vietnam during the years 1857 to 1858, related that a short, thin, red variety of sugarcane cultivated around Saigon was considered the best, see Brown, E. (1), p. 209.

[e] *Khâm Định Đại Nam Hội Điện Sự' Lệ*, 66, pp. 1b–3b. Crawfurd ((1, p. 461), writing of the 1820s, mentioned that a considerable quantity of sugar was produced in Quang-Ngai province, and that it was also manufactured in the provinces of Quang-Nam and Hue[16].

[f] The Cambodians called Ha Tiên Banteay Meas, and the Portuguese named it Ponthiamas.

[1] 大南寔錄 [2] 楊彥迪 [3] 陳上川 [4] 明香社 or 明鄉社
[5] 清河社 [6] 嘉定 [7] 廣南 [8] 廣義 [9] 鄭玖
[10] 雷州 [11] 河僊 [12] 港口國 [13] 本底國 [14] 龍門總兵
[15] 高雷廉總兵 [16] 順化

and thereafter Ha Tiên became a vassal state of Quang-Nam,[a] and served as a focal point for attracting Chinese to the area. The efforts of these Chinese leaders and the Nguyên rulers in promoting foreign trade, combined with the strong contingent of Chinese merchants in Quang-Nam,[b] encouraged the production of sugar as a trade commodity. About +1750 Pierre Poivre praised the white sugar at Hôi-An (Faifo) for its excellent quality and cheapness, remarking that it attracted foreign merchants, particularly the Chinese, to that and other ports in central Vietnam.[c] The celebrated late Lê dynasty Neo-Confucian philosopher and official Lê Qúy-Đôn[1] (+1726 to +1784) wrote in his *Phu Biên Thup Luc*[2] (Miscellaneous Records of Pacifying the Border) of +1776 that Quang-Nam produced sugar candy, white sugar and *sha-thang*.[d]

By +1749–50 when Poivre visited central Vietnam, the Nguyên policy of Chinese assimilation into Vietnamese society had been so successful that the methods of sugarcane cultivation and black sugar boiling had spread to indigenous cultivators as well. Vietnamese undertook the actual work of growing the sugarcane, crushing it and boiling it into a syrup. They transported it in syrup form to nearby markets for sale to merchants, who refined it into white sugar, selling large quantities to other merchants for export to China.[e] The transfer of Chinese sugar-making technology spread quickly, as by the mid +18th century, at least, white and brown sugar was also produced in the heavily populated Tongking area,[f] where the Vietnamese cultivated the land and the Trịnh rulers restricted the activities of the Chinese.

Imperial monopoly

After the first Emperor of the Nguyên dynasty, Gia-Long[3] (+1762 to +1820), united Vietnam on the fall of the Lê dynasty, he turned to sugar as a means of enriching the Imperial coffers sadly depleted by the ravages of civil war.[g] In +1797 and +1798 Gia-Long, in the words of John Barrow, the author of *A Voy-*

[a] The son of Mac Curu, Mac Thien-Tú[4], the celebrated author of the poetical work *Ha Tiên Thập Vịnh*[5], encouraged foreign trade during the first half of the +18th century.

[b] Fujiwara (*1*), p. 203.

[c] Poivre (1), pp. 112–13.

[d] *Phu Biên Thup Luc*, *quyen* 4, pp. 38a–38b; *quyen* 4, p. 40a; *quyen* 6, p. 27a; *quyen* 6, p. 29b. It seems from *quyen* 6, pp. 26b–27a that Phú-Yên[6] prefecture was the large producing area.

[e] These merchants were undoubtedly Chinese as almost all the merchants in central Vietnam during the +17th, +18th and 19th centuries were either Chinese nationals, or Chinese males born of Vietnamese mothers. For the Chinese as merchants in central Vietnam see Fujiwara (*1*), pp. 257–70.

[f] Richard ((1), vol. I, pp. 334–7), whose work was published in +1778, recorded sugarcane crushed under *une meule* (an edge-runner or possibly a *frangourinier*) turned by a cow and large quantities of white and brown sugar being exported to China. During the early 19th century we hear of Chinese resident in Tongking making sugar candy for export to China, see Montyon (1), pp. 113–14.

[g] White (White, J. (1), p. 79) remarked that Vietnamese officials who visited his ship in Turon told him that the civil wars had devastated the country and it was 'now slowly emerging from a state of poverty, in which it had been plunged by the excesses of the hostile troops'.

[1] 黎貴惇 [2] 撫邊雜錄 [3] 嘉隆 [4] 鄭天賜 [5] 河僊十詠
[6] 富安府

age to Cochinchina ... of +1806, 'caused large tracts of land to be prepared for the culture of the sugar-cane'.[a] In addition, John White related that in 1819 the viceroy at Saigon informed him that the Emperor Gia-Long had purchased all sugar produced in the region at the price of 8 *quans* per picul, ordering growers to plant double the acreage of cane in the following season. The new Emperor strove to promote sugar production, and at the same time keep marketing under his own control, but Western trading missions bemoaned the consequent reduction, in the amount of sugar available on the free market, caused by this monopoly.[b]

The idea of the State purchasing sugar at a fixed price did not begin with the Nguyên dynasty. Lê Qúy-Đôn in his official investigation of Quang-Nam after the attack by Trịnh forces during the first half of the +1770s showed that the rulers of the Kingdom, the Nguyên family, purchased sugar at a fixed price from specific places under their jurisdiction:[c]

Phu-Teng sugar[1] produced in Diên-Ban prefecture[2] is light, soft and white in colour, and a single piece weighs one *chin*[3] (0.6 kilos). The Nguyên family ordinarily ordered the Recording Official of Quang-Nam (*Quang-Nam Ky Luc Quan*[4]) [to purchase] 300 *chin* (180 kilos) for a fixed period, 300 *chin* for a fixed period[d] or 800 chin (480 kilos) for a fixed period in Dông Shen Xa[5] [village], Xuân Dai Châu[6] as offerings on the anniversary of the death of parents and ancestors, paying 24 *van*[7] for each *chin*. There are no tax regulations, and both the Châu[8] and Xa[9] [villagers] are able to manufacture sugar candy (*ping-thang*[10]), each time altogether submitting 48,320 *chin* (28,992 kilos) annually.

The Emperor of the new Nguyên dynasty merely built upon precedent in tightening the monopoly over sugar in central and south central Vietnam.

After the death of Gia-Long, his successor, Minh Mang[11] (+1791 to 1841), the second Emperor of the Nguyên dynasty, who reigned from 1820 to 1841, took measures to rectify the excesses of the monopoly.[e] The easing of government

[a] Barrow (2), pp. 273–4.

[b] When the American captain John White visited the country between 1819 and January 1820 in two ships for the purpose of trade, however, contrary to the accounts of +18th-century European visitors, he discovered very little sugar available for purchase on the market in Saigon. White maintained that the number of ships visiting Saigon had decreased between 1805 and 1819, and that there had been a decline in trade in general due to the regulations requiring ships to carry rice and other provisions free of charge for the Emperor, see White, J. (1), pp. 259–60. In short, White attributed this decline to 'the tyrannical nature of the government' as do many other late +18th- and early 19th-century visitors, see White, J. (1), p. 261.

[c] *Phu Biên Thap Luc, quyen* 6, p. 27a.

[d] This repetition may derive from an error in handcopying as the original is a manuscript.

[e] In an Imperial Edict issued in 1820 included in the *Khâm Định Đai Nam Hội Điên Sự' Lệ, quyen* 66, p. 1b Minh Mang proclaimed: 'Since ascending the throne I have earnestly considered the needs of the people and sought to relieve their sufferings. The regulation concerning the purchase of *sha thang*[12] originally aimed to enrich the state and profit the people. I have heard that yamen clerks (*lai-dich*[13]) extort money from the people on the pretext of public affairs and harm the merchants. Furthermore many of them use the prohibition on selling [*sha-thang*] to obtain wealth by blackmail. I hereby order the two Grand-defenders (*trân-thân*[14]) of Quang-Nam and Quang-Ngai provinces to ease the restriction against selling sugar in order to improve the livelihood of the people.'

[1] 普笃糖 [2] 奠盤府 [3] 斤 [4] 廣南記錄官 [5] 東審社
[6] 春臺洲 [7] 文 [8] 洲 [9] 社 [10] 水糖
[11] 明命 [12] 沙糖 [13] 吏役 [14] 鎮臣

controls made more sugar available for non-monopoly merchants to purchase and export. Nevertheless, it would seem that purchases by the State were never completely abolished.[a]

Technology transferred

The inhabitants of the Tongking region had from ancient times boiled the juice of sugarcane to make syrup, amorphous sugar (*shih-mi*) and wine, but did not manufacture crystallised sugar.[b] The development of an East Asian type of pre-modern sugar production had to await the transfer of the Chinese vertically mounted double-roller mill and crystallisation techniques, and the earliest detailed description did not appear until the visit of Pierre Poivre to central Vietnam in +1749–50. Poivre's account indicated great similarity to the methods we have already outlined for China in the Pearl River delta:[c]

When the Cochin-Chinese prepare the ground for the sugar-cane, they turn it up to the depth of two feet; this operation is performed with a plank.[d] They then plant joints or eyes of the cane, three and three together, in a horizontal position, almost in the same way as they plant vines in many French provinces. These slips are planted chequer-wise, about eighteen inches deep in the ground, six feet distant from each other; they perform this operation towards the conclusion of the rainy season, so that the slips may be sufficiently watered, till such time as they have taken root. During the first six months, they give them two dressings with a kind of pick-axe, in order to destroy the weeds, and preserve a moisture about the roots of the canes, by heaping the earth around them.

They gather the first crop twelve, and sometimes fourteen, months after the plantation. By this time the canes, though planted at six feet distance, become so bushy, that it is impossible to enter the field, without making use of an axe to clear your way.

The attention given to the number of eyes on a cane sett, leaving six feet (approx. 1.8 metres) between the cane rows, weeding and the hilling of soil are all characteristic features of Chinese sugarcane agriculture as we have seen earlier. Edward Brown, who was detained in Vietnam from 1857 until 1858, observed cane setts planted vertically, in his own words 'after the French fashion by sticking the piece diagonally in the ground', and commented that 'some, however, finding the cane had suffered in times of drought, have adopted other modes'.[e] As demonstrated earlier, the Chinese planted horizontally and diagonally depending on the rainfall, and since the diagonal method had been documented

[a] For example, the *Khâm Dinh Đại Nam Hội Điển Sự' Lệ, quyen* 66, pp. 1b–4a recorded that the State purchased 200,000 catties [120 tonnes] of *sha-thang* from Quang-Nam province in 1826, 100,000 catties [60 tonnes] in 1830, and 90,000 catties [54 tonnes] in +1839. Crawfurd ((1), p. 542) related that a merchant ship and a brig belonging to his Cochin-Chinese Majesty visited Singapore for three consecutive years during the mid-1820s, so there is every possibility that the Emperor exported the sugar purchased by the State.

[b] See (*b*), above.

[c] Poivre (1), pp. 106–7.

[d] The plank was used as a harrow in South-East Asia, but here Poivre described the final operation and not the initial ploughing.

[e] See Brown, E. (1), p. 208.

for the Pearl River delta region by the late +17th century at least, this was a Chinese rather than a French influence.

Poivre's description of refining white sugar also displayed distinctive Chinese features;[a]

After the canes are cut, and tied up into bundles, they are carried to the mills, to extract their juice. As these engines have been described by many travellers, I shall not here describe their form, which much resembles those of the West-Indies: they employ oxen or mules, instead of water, to set the two cyclinders in motion, between which the sugar-canes are pressed.

When the juice is extracted, they boil it a few hours in large kettles, in order to evaporate part of its water: it is then carried to the neighbouring market, and sold in that condition. Here the industry and the profits of the Cochin-Chinese planter ends. The merchants buy the juice, which resembles pure water; they re-boil it, throwing some alkaline substance, such as the ashes of the leaves of the musa or bananier, and shell-lime into the kettle; they know no other; these ingredients throw up a thick scum, which the refiner carefully takes off: the action of the alkali hastens the separation of the salt from the water, and by the force of boiling, reduces the juice of the cane to the consistence of syrup. As soon as this syrup begins to granulate, they decant it into a great earthen vessel, where they cool it about an hour; when a kind a crust, still soft, and of a yellowish taint, appears on top of the syrup; then they immediately empty it into a vessel of a conic shape, which they name a FORM. Without this intermediate operation of cooling the syrup, it would harden into a mass and not being granulated, would of consequence want one material quality of sugar.

These sugar-cones, or forms, are of backed earth, in Cochin-China, like those of our West-India colonies, about three feet high, pierced at their narrow extremities, and commonly hold about forty or fifty pounds of sugar. These FORMS, when full, are placed on another earthen vessel, the mouth of which is proportioned to receive the narrow end of the cone, and must be large enough to hold the coarse syrup, which distils from the sugar, through some straw which imperfectly stops up the little opening in the bottom of the FORM.

When they suppose the syrup has acquired the consistence of salt on every part of the cone, they then proceed to whiten and purify it. They dissolve a fine sort of whitish clay in a trough, with such a quantity of water as, when thus prepared, prevents it from having too much consistence; they then lay it upon the surface of the sugar with a truel, to the thickness of about two inches, in the void space left at the top of the FORM by the condensing of the sugar, after purging itself of the coarser syrup or melasses. The water contained in the clay penetrating by degrees into the mass, washes it, and carries off insensibly the remaining syrup, and every foreign particle that adheres most closely to the sugar. When the clay hardens, they replace it with a fresh quantity, diluted as the first: this operation, which lasts about twelve or fifteen days, is the same here as in our West-India colonies. Some refiners of Cochin-China, however, have a different method. Instead of clay, tempered thus with water, they cut the trunk of the musa or bananier into little pieces, which they place upon the sugar: the trunk of this tree is very watery; the water of a detergent quality; distills from the fibres, which envelope it, in very small drops. Those who follow this method pretend, that the operation

[a] Poivre (1), pp. 107–12.

is thereby rendered less tedious, and that the sugar acquires a more beautiful colour.

The process of the Cochin-Chinese, in refining their sugar, goes no further: they know nothing about the stoves in use in the West Indies ...

The claying operation was exactly the same as that described in the *Thien Kung Khai Wu*, and the influence once again was Chinese rather than French West Indian. Secretions from the trunk of the banana plant served as a substitute for clay when it was not available locally, or too expensive; here again the principle of water percolating down through the cone and washing the molasses off the sugar remained the same as with clay.[a] The application of the plantain for draining sugar may possibly have pre-dated the arrival of Chinese technology; George Staunton, who visited central Vietnam in +1793 left a glowing account of a method of claying without cones:[b]

In purifying sugar, after the gross syrup had been drained from it, and it was become already granulated and solid, they sometimes placed it in layers of about one inch in thickness and ten in diameter, under layers of equal dimensions of the herbaceous trunk of the plantain tree; watery juices exsuding from which, and filtrating through the sugar, carried down with them all the dross which had been boiled up with it, leaving the pure sugar crystallized and white. It was then very light, and almost as porous as a honeycomb. When dissolved, it left no sediment at bottom. This method appears, certainly, to be an improvement on the usual mode, elsewhere, which consists in pouring the sugar, as soon as granulated, into vessels of the form of inverted cones, and placing a layer of wet earth upon the upper surface of the sugar. That upper surface is, thus, indeed, much purified; but never so perfectly as in the Cochin-Chinese method. The grain of the sugar is more broken, and the inverted point of the loaf always retains more dross than does its base, to which filtrating liquid had been more immediately applied.

Apart from clayed white sugar (*pai-thang*), we also know from the description in the *Flora Cochinchinensis* of the good Father Joannis de Loureiro that central Vietnam produced sugar candy (*ping-thang*) at the time of Poivre's sojourn.[c]

Now that we have established the widespread application in central Vietnam of *Thien Kung Khai Wu* technology, albeit with a few local adaptions, we must pose the question of when the transfer took place. In view of the fact that it had diffused out amongst the indigenes in central Vietnam by the +1740s, we may assume a +17th-century transfer. Since +17th-century European visitors to the Tongking region mentioned nothing of crystal and refined sugar,[d] I postulate that the Chinese technology entered the country through central Vietnam,

[a] Mac Micking ((1), p. 283) reported a similar practice in the Philippines during the 19th century: 'Besides clay, some portions of the stem of the plantain-tree are said to have the power of extracting the impurities from sugar, and in some districts are said to be preferred to clay for that purpose, being chopped up in small pieces, and spread over it.'

[b] Staunton (1), vol. 1, p. 388.

[c] de Loureiro (1), vol. 1, p. 52.

[d] Samuel Baron, writing in +1685, commented (Baron (1), p. 6): 'Here are great plenty of sugar-canes, but they have no skill to refine the sugar they make from them; however, they do it after their manner, and use it, but not after meals, as *Tavernière* faith, for concoction.'

brought by the many immigrants arriving from south China in the same century. The motivation for commencing sugar production derived from the difficulty of trading with China due to the fall of the Ming, and early Chhing prohibitions on foreign trade, which inadvertently created a market for Vietnamese sugar in Japan. Vermilion-seal ships, *Shū'in-sen*[1], carried black sugar (*hei sha-thang*[2]) to Japan from central Vietnam (*Chiao-Chih*) and Cambodia (*Chien-Phu-Chai*[3]) between +1615 and +1643.[a] This black sugar could hardly have been amorphous sugar for it would have deliquesced on a long ship haul overseas presenting handling problems. I suggest that it was made by *Thien Kung Khai Wu* methods, for the contemporary Japanese preferred black sugar rather than white sugar.[b] Here we can surmise a transfer by Chinese merchants desiring to establish production bases overseas to meet the demands of the intra-Asian markets.

Overseas markets

Overseas markets played a major role in the development of sugar production based on Chinese technology outside China. Central Vietnam exported sugar to Japan during the early +17th century, and most probably to China during the same period as well.[c] In addition, Vietnamese sugar found a new outlet in the British ports in the straits of Malacca after the establishment of Singapore in +1819.[d] During the early 19th century the Chinese in Tongking

[a] Iwao (*2*), p. 3 and Iwao (*3*), p. 288. Borrus, whose work was published in +1633 recorded much sugarcane grown, but mentioned nothing of sugar as an article of trade (Borrus (*1*)).

[b] A Portuguese source of the late +16th century reported that the Japanese preferred black sugar rather than white sugar, for which there was little demand there, see Iwao (*2*), p. 2.

[c] An official document sent from Quang-Nam to the Chinese interpreters in Nagasaki in +1688 stated that *phi-thang*[4] or hide sugar, along with ivory and aromatic trees (*hsiang-mu*[5]), constituted the principal products of their kingdom, see *Ka-I Hentai*, pp. 1035–6. Poivre ((1), p. 113), describing the sale of white sugar at the port of Hôi-an (Faifo) related, 'There is a great trade in this commodity. The Chinese alone, whose lands do not produce enough for their own consumption every year, transport above forty thousand barrels, weighing about two thousand each, from Cochin-China.' For such large production to have taken place the industry must date back to the +17th century. Note that the figures for production and prices of sugar in Poivre's work must be viewed with caution. He may have exaggerated as the purpose of his detailed description of sugar lay in illustrating that free men in central Vietnam cultivated sugarcane and produced sugar, much more efficiently than slaves in the West Indies. John Barrow, who visited central Vietnam with Sir George Staunton in +1792 and +1793, remarked that from Turon sugar was 'exported to the China market in cakes, which in colour, thickness and porosity resemble honeycomb' (Barrow (*2*), p. 316). In the 1820s Crawfurd ((1), p. 474) stated that the greater part of the total annual export of Vietnamese sugar which ranged between 20,000 (approx. 1,200 tonnes) and 60,000 piculs (approx. 3,600 tonnes) *per annum* was sent to China from Hôi-An (Faifo).

[d] Crawfurd (1), p. 513. Crawfurd ((1), p. 513 and pp. 539–42) estimated that 26 junks of a total tonnage of more than 4,000 tons went from Vietnam to the Straits settlements in 1824 and that the number increased in the years thereafter; Singapore soon became an entrepôt for sugar of all grades from Siam, the Philippines, Vietnam, and, during the early 1820s, confectionery and sugar candy direct from China. He noted that sugar was a staple import from Siam, Cambodia and Vietnam (p. 542), and reported exports from Singapore of 27,415 cwts, 20,000 cwts, 33,600 cwts and 27,500 cwts for each year from 1823 to 1826 (p. 544). It is estimated that roughly 5,000 piculs [300 tonnes] of sugar were exported annually from Vietnam to the European settlements in the Straits of Malacca and Singapore in Chinese junks during the 1820s, and by the 1850s at least, a few European-built vessels owned by Chinese at Singapore sailed to Saigon to trade in addition to the hun-

(*cont.*)

[1] 朱印船 [2] 黑沙糖 [3] 柬埔寨 [4] 皮糖 [5] 香木

made sugar candy for export to China.[a] Chinese merchants may have even introduced *Thien Kung Khai Wu* style technology to Tongking much earlier in the +17th century with the express purpose of promoting the production of sugar, so dearly desired as a valuable commodity for trading with China. As with all other aspects of commerce in Vietnam, a few Chinese merchants dominated this trade.[b] An English seaman detained in Vietnam between 1857 and 1858 remarked that merchants controlled almost all of the commercial production of sugar by advancing funds to growers and sugar makers, who were thereby obligated to sell their sugarcane and sugar to them. These putting-out merchants exported the best sugar to two or three Chinese merchants in Singapore who contracted for it.[c] Export-orientated production was not only generated by capitalist systems, but thrived in pre-modern economies as well.

Nguyên rulers did well in proclaiming a monopoly over sugar for the Vietnamese had already acquired the technology for its production, and the marketing side could be easily controlled through the merchants. However, the consequent reduction in the amount of sugar on the open market resulted in what John White claimed was a distinct deterioration in quality; 'their sugar, which was formerly clayed, and highly esteemed, is now brought to market in a raw state, and that in very small quantities'.[d] John Crawfurd, on his visit during the early 1820s, attributed this situation to the following factor:[e]

> The sugarcane is cultivated to a considerable degree in the provinces of Kwang-ai [Quang-Ngai] and Kwang-Nam [Quang-Nam], which lie immediately to the southward of the capital; but not much in Kamboja [Cambodia], and still less in Tonquin [Tongking]. The Cochin Chinese themselves are both the cultivators and manufactures, and receive no assistance from the Chinese, as in the neighbouring countries; and from hence, I have no doubt, arises the inferiority of the Cochin Chinese sugar, which ranks below that of Siam, of the Philippines, and of Java, being dark in colour and badly granulated.

Footnotes to page 435 (*cont.*)

dreds of Chinese junks that came annually, see Crawfurd (1), p. 474; Brown, E. (1), p. 267. The King of Vietnam is also said to have owned ships which traded at Singapore (probably carrying Vietnamese sugar) and returned with European goods such as calicoes, drillings, see Brown, E. (1), pp. 238–9. During the same period, Con-kow or Artien-Ting functioned as a depot for sugar and other local produce exported to Siam, Singapore and China.

[a] Montyon (1), pp. 113–14.

[b] Brown, E. (1), p. 286.

[c] Despite laws prohibiting its importation, merchants in Singapore and China sent opium to their Chinese agents in Vietnam to pay for export cargoes, see Brown, E. (1), pp. 286–7. We can safely assume that opium acted as a means of making payments for export sugar. Sugar production under a putting-out system was common in south Taiwan during the +18th and +19th centuries, and was probably the main technique Chinese merchants resorted to for obtaining a stable supply of sugar in China after the +17th century, see Daniels (2). Such a putting-out system enabled merchants to regulate the supply of sugar to meet changes in the demands of the pre-modern Chinese domestic market. When Chinese merchants began operating in central Vietnam after the +17th century they probably found that putting-out proved the easiest way of securing a constant supply of sugar for the home Chinese market.

[d] White, J. (1), p. 261.

[e] Crawfurd (1), p. 474.

Most of the sugar sold on the markets in East and South-East Asia was manufactured by Chinese, or at least under their supervision, but the transfer of sugar production to indigenous Vietnamese hands obviously occasioned a change in the quality of the final product. Once the Vietnamese started producing sugar that did not meet the quality specifications required for Chinese merchant controlled markets in East and South-East Asia, they found it increasingly difficult to compete with sugar made by the Chinese elsewhere in South-East Asia.

We can speculate that the tightening of State control over the sale of sugar in the early 19th century reduced the influence that Chinese merchants wielded over production, and the removal of these middlemen occasioned a decline in quality control. In putting-out systems, merchants controlled all aspects of production, especially the quality and quantity of the commodity, by advancing funds. Vietnamese producers probably relied so heavily for quality control on Chinese merchants familiar with the requirements of the export market, that they found it difficult to make sugar of the requisite quality without their supervision. Chinese merchants, however, did continue to handle the shipping of sugar and other produce.[a]

The monopoly by the Nguyên dynasty greatly reduced the production of white sugar. It would have been unprofitable to manufacture white sugar if it could not be sold for a good return, since the operation required substantial capital; black sugar had to be reboiled and clayed. Forced sale at a low price to the government naturally discouraged vigorous merchant activity, but it ensured that the State obtained large quantities of black sugar from agriculturalists, who were capable of growing sugarcane and making black sugar without any help from merchants. In fact the State, in offering a fixed price for black sugar, merely gained control of the putting-out system that merchants had previously fostered to procure sugar. In any case, the State probably relied on merchants to administer the monopoly.

We may conclude that Chinese immigrants from the great sugar-producing regions of south China brought *Thien Kung Khai Wu* sugar technology to central Vietnam sometime during the +17th century. As a result of the Nguyên rulers' policy of assimilating Chinese immigrants, the Chinese methods of sugarcane cultivation, milling and sugarboiling diffused out amongst the Vietnamese as well. Assimilation of the Chinese into Vietnamese rural society, especially into the newly forming rural society in Gia-Dinh (Saigon) prefecture, enabled relatively rapid transfer and diffusion to the indigenes, whereas the mature nature of rural villages in Tongking kept them out. It is interesting that the process of diffusion resulted in the incorporation of some indigenous practices such as the use of plantain for claying.

[a] Crawfurd ((1), p. 514) mentioned that all branches of the foreign trade of Vietnam were conducted by the Chinese 'who are both the merchants, mariners, and navigators' of the country.

(iii) *The Indonesian archipelago*

The earliest description of Chinese sugar technology in the archipelago known to us, occurred in the *Herbarium Amboinense* of Georg Everhard Rumpf (Rumphius), who arrived at Ambon (Amboina) in the service of the United East India Company in the +1650s:[a]

> Cut stalks with leaves removed are pressed between two rollers made of hard 'cussambi' wood which are turned by cattle. Then the clear juice is taken away in channels, constructed from cut cattle hide, into large vessels for boiling. These vessels have a lower part of iron [i.e. pan] which is joined to the oven. On the other hand the top part of the boiling pan is built up with burnt stones which extend high so that the whole is seen to be a large boiling pan.
>
> To this then juice is introduced and a strong fire built up. As the syrup diminishes new juice is added slowly, and the fire is eased until the juice becomes dark and thick. From this then it is poured into dishes made of earth and deep, or into great clay jars which are placed in a smoky warm place. Where the sugar is dried up of which the upper part is white and conglomerated and called cakes of sugar, below part indeed turned golden brown, and is known as muscovado sugar.
>
> Out of the white sugar the Chinese make sugar candy. It is dissolved in a large boiling pot into which the whites of eggs are added, [the impurities rising to the surface] carefully skimmed off, and at last some chicken fat added. This is needed, it is said, in order to make the sugar transparent.

Once again we witness the Chinese double-roller mill, boiling and skimming techniques so characteristic of the *Thien Kung Khai Wu* methods employed both at home and abroad. From the description of several pans enclosed in masonry, we see the clover-leaf triple-pan arrangement, and the crystallisation of massecuite in earthenware jars resembles the *pilone* method documented for the Philippines, while reboiling with egg white clarification was standard Chinese practice for making sugar candy.[b]

Sugar production played an exceptionally important role in the economy of Batavia and its environs. I have assembled the available data on sugar mills located in Batavia and Preanger between +1596 and +1779 in Table 19. Chinese owned most of the sugar mills before the brutal massacre of +1740, but their level of ownership fell drastically thereafter due to Dutch restrictions. For example, in +1731 Chinese owned all but 5 of the 131 mills, but in +1779 they only possessed 26 of the 55.[c] Nevertheless, even if owned by Dutch or Javanese, the Chinese usually managed the mills, and this dependence on Chinese skill continued until the 1830s at least, when the Cultivation System got underway.[d] In the latter half of the +18th century sugar mills, usually located along rivers in a position central to the cane fields, appear to have been relatively

[a] Rumphius (1), vol. 5, p. 188.
[b] See pp. 388, 395–8, above.
[c] Cobban (1), p. 132.
[d] *Ibid.*, p. 133. For the Cultivation System see van Niel (1).

Table 19. *Number of sugar mills and output per mill in Batavia and Preanger, +1596 to +1779*

Year	No. of sugar mills	Total production	Tonnes/mill
+1596	2 or 3	60 to 120 tonnes	20–60
+1602	4 or 5	180 tonnes	40
+1650	20	420 tonnes	21
+1710	131	2,751 tonnes	21
+1745	65	1,170 tonnes	18[a]
+1750	77	1,380 tonnes	18[a]
+1779	55	4,800 tonnes	87

Campbell (1), vol. 2, pp. 923–4.

[a] Campbell ((1), vol. 2, p. 911) noted that at this time production was limited to 300 piculs or 18 tonnes per sugar mill.

large operations crushing 24 hours a day, using 32 buffaloes, and on average employing as many as two hundred people. Chinese overseers supervised the harvest, and we also find standard Chinese cane-growing techniques; irrigation by means of buckets or sometimes foot-pumps, and application of organic fertiliser and manure to the canefields.[a]

The Chinese manufactured sugar at Batavia for both the European and Asian markets. On the first visit of the Dutch to Java in +1596, they discovered Chinese operating two to three sugar mills at Jacatra, the site on which they later erected the city of Batavia. Just six years later in +1602, Jacatra counted four or five sugar factories and some others making *arak*.[b] The United East India Company began laying out plantations for the cultivation of sugarcane in +1637, but production for export on a significant scale did not get underway until the +1640s. Javan sugar had to compete with consignments from tropical America on the Amsterdam market as well as from Taiwan on the Asian market. The loss of the Dutch trading station on Taiwan strengthened the position of Javanese sugar in intra-Asian trade, and from the +1670s and +1680s onward it captured markets that it held until the end of the +18th century at least, in Japan, Persia, Surat and Coromandel. Between +1680 and +1709, 25,863 tonnes of powder sugar[c] and 4,036 tonnes of sugar candy[d] went to the company's factories in these four places. Exports to Amsterdam also rose with

[a] Cobban (1), pp. 132–4. Cobban also related that by +1779 lack of fuel in the environs of Batavia had reached crisis proportions, and the Chinese practice of using only one boiling pan was blamed. As the Chinese employed the three-pan boiling arrangement on Ambon during the +1650s, it is not clear why they used the one-pan system near Batavia.

[b] Campbell (1), vol. 2. p. 923; Deerr (1), pp. 217–18.

[c] Known in China as *ping-hua*[1] or crystal flowers, 'is the name given to the pounded and sifted sugar candy, little of which is now exported', according to S. Wells Williams (Williams, S. W. (1), p. 140).

[d] The Chinese name was *ping-thang*[2].

[1] 冰花 [2] 冰糖

annual consignments ranging from 1,500 to 3,000 tonnes between +1719 and +1727; sugar flutes, vessels specially designed to carry between 275 and 300 tonnes each, came into service after +1715 for express runs to Holland. Increases in exports to Europe continued thereafter until +1740 despite injunctions from the company directors for reductions.[a]

The notorious massacre of 10,000 city-dwelling Chinese inside Batavia in +1740, and many more residing in its environs and in other parts of Java, had adverse effects on sugar production. According to Kemasang (1) the failure of extortionate poll taxes, and segregation policies designed to curtail the seemingly inordinate amount of control the Chinese exercised over local business activities, in and around Batavia, led the Dutch to commit this atrocity; it was part of a premeditated plan by the Dutch to usurp the power of the Chinese. This massacre of Chinese in Batavia greatly reduced sugar output, and production did not start to recover until +1750.[b] To fill the vacuum in the wake of the massacre, the United East India Company leased former Chinese tenanted land to Europeans and Javanese; but the truth of the matter was that the Chinese proved so essential both as skilled technicians and overseers, that the Dutch could not do without them. They remained of vital importance to sugar production until the beginning of the Cultivation System in 1830.

Sugar making by Chinese was by no means only restricted to Batavia. With demand from the United East India Company rising, Chinese entrepreneurs opened mills in the officially autonomous States of indigenous potentates such as Banten, Ceribon and the littoral of Central and East Java from the +1650s.[c] Rumpf confirmed similar activities for Ambon (Rumphius (1)), but from the viewpoint of the history of technology the most interesting part of the archipelago was the island of Sumatra. Here the indigenes wielded hand-operated vertical roller mills with elongated worm gears. William Marsden, writing of his experiences on the island in the +1770s, remarked in his *The History of Sumatra*: 'The rollers of the mill used for this purpose are worked by the endless screw instead of cogs, and are turned with the hand, by means of a bar passing through one of the rollers which is higher than the other.'[d] Worm gearing was an Islamic technology, and after the second half of the +18th century when European planters introduced Chinese technology, skills and labour, Sumatra marked the eastern extent of Chinese roller-milling technology.

Henry Botham, an Englishman who operated a sugar factory at Bencoolen on Sumatra during the +1770s, to whom I have referred many times before, achieved notoriety for replacing slaves with Chinese contractors. In the words of William Marsden:[e]

[a] Export trade of Javanese sugar from Glamann (1), pp. 152–66.
[b] *Ibid.*, p. 166.
[c] Kemasang (1), p. 66.
[d] Marsden (1), p. 188.
[e] *Ibid.*

Many attempts have been made by the English to bring to perfection the manufacture of sugar and arrack from the canes; the expenses, particularly of the slaves, were always found to exceed the advantages. Within these few years (about 1777) that the plantations and works were committed to the management of Mr Henry Botham, it has manifestly appeared that the end is to be obtained, by employing the *Chinese* in the works of the field, and allowing them a proportion of the produce, for their labour. The manufacture had arrived at considerable perfection, when the breaking out of war gave check to its progress; but the path is pointed out, and it may be worth pursuing. The sums of money thrown into Batavia for arrack and sugar have been immense.

Under the Chinese system, production was organised by managing numerous small individual units which undertook the actual work. Mr Botham related Chinese management techniques in the following way:[a]

The proprietor is generally a rich Dutchman, who has built on it substantial works; he lets the estate (say of 300 or more acres) to a Chinese, who lives on, and superintends it, and who relets it to free men, in parcels of fifty or sixty acres, on condition that they shall plant it in canes, for so much for every pecul, $133\frac{1}{3}$ lbs of sugar produced. The superintendent collects people from the adjacent villages, to take off his crop. One set of task-men, with their carts and buffaloes, cut the canes, carry them to the mill, and grind them; a second set boil them; a third clay and basket them for market, at so much per pecul: thus the renter knows with certainty what every pecul will cost him. He has no unnecessary expense, for when the crop is over, the task-men go home; and for seven months in the year there only remain on the estate the cane-planters, preparing the next crop. By dividing the labour, it is cheaper and better done.

As we saw earlier, the practice of landlords contracting with their tenants to grow sugarcane became quite common in China after the +17th century, and similar contracts between peasants and merchants became even more frequent. The arrangement described by Mr Botham for Sumatra was merely an extension of homeland practice abroad.[b] Since I have already dealt with the agronomic practices at Bencoolen under (D), above, I will not repeat myself here. Suffice it to say that the Chinese contractors used mould-board ploughs and traction spades. In the Straits Settlements on the Malay peninsula, where Chinese flocked to set up sugar mills from the early 19th century,[c] as well as contracting out their skills and labour to European planters, contractors preferred hoes to ploughs, because they kept more of their compatriots in work.[d]

[a] East India Company (1), p. 83.

[b] It should be remembered that Henry Botham tried exceptionally hard to illustrate the superiority of free labour over slave labour, citing the example of Chinese management techniques. The purpose lay in furnishing evidence in favour of emancipation in the West Indies, and did not involve a full description of all Chinese technology; in fact he omitted the vitally important crushing process. However, the Western reader should not be led away by his own ignorance; Chinese management methods as practised in the homeland were certainly not devoid of exploitation, and the so-called labourers were never as free as Henry Botham made them out to be. Indeed merchants kept many of the sugarcane-growing peasants in south China in a state of perpetual debt by loaning them money to maintain production. For an account of the control of sugar production in south China by merchants and landlords during the +18th and 19th centuries see pp. 115–25, above.

[c] See Tan (1).

[d] Wray (1), pp. 130 and 135.

(iv) *Siam*

Chinese sugar technology seems to have been transferred to Siam twice. The first instance occurred during the early +17th century, and the second in the early 19th century.

Despite poor documentation for the first occasion, I place it in the early +17th century since studies of contemporary international trade indicate the export of black Siamese sugar to Europe by the United East India Company, and to Japan by the Vermilion Ships (*Shu'in-sen*) in +1634.[a] Viraphol thought that the 'raw sugar' exported from Siam to China and Japan did not derive from the sugarcane.[b] The principal question is what type of sugar was being referred to, cane sugar or palm sugar? The Tokugawa Bakufu conducted intelligence investigations of the contemporary political, social and economic situation in South-East and East Asia during the +17th century. The archives of the Bakufu interpreters, who interrogated the crews of Chinese junks visiting Nagasaki, provide some information, albeit inconclusive, on sugar production in Siam.[c] In a testimony, dated the eighth day of the seventh lunar month +1690, the officers of a Chinese junk out of Siam submitted the following statement:[d]

> [Siam] is a country which produces a considerable quantity of *hei sha-thang*. It cannot be grown in water and is produced [on dry land] near the hills. Due to a poor harvest of *hei sha-thang* this year the Siamese ships visiting Japan all carry smaller quantities of it [than usual]. Each time our ship comes it usually carries several 100,000 *chin* [approx. 120 tonnes] of sugar (*sha-thang*) but in this shipment we only have 70,000–80,000 *chin* [42–48 tonnes] on board. In addition for the past several years a quota system of trading has been adopted in your country [Japan],[e] and we have not been able to sell all of the sugar that we have brought. If we take the unsold sugar back with us, it will all dissolve into water due to the moisture from the sea by the time we reach Siam, and we will be unable to cover costs. This is another reason for the decrease in shipments of sugar [from Siam to Japan], but, as mentioned earlier, the exceptionally poor harvest has contributed to us bringing less sugar this year as well.

The statement that sugar cannot be grown in water (refers to cultivation in wet rice fields), but was cultivated near the hills on dry non-paddy land, can only

[a] For Europe see Glamann (1), p. 153. Iwao ((3), pp. 295–6) recorded the importation into Japan in +1634 of 4,000 to 5,000 *chin* [2.4 to 3 tonnes] of black sugar.

[b] Viraphol ((1), p. 178) quoted a Thai reference which said that George White of the British East India Company reported from Ayudhya in +1678 that sugar was produced in great quantities, and exported to Malacca and Japan.

[c] Some of the written transcripts of the testimonies made by the Chinese crews refer to *hei sha-thang* being produced in Siam during the +1680s and +1690s. *Ka-I Hentai*, vol. 1, pp. 307–10 contains three testimonies obtained in +1680 from three Chinese junks from Siam which reported a flood that caused the price of raw sugar to rise. *Ka-I Hentai*, vol. 2, p. 1281 is the reference for +1690. Also see Ishii (1), pp. 169–70.

[d] *Ka-I Hentai*, vol. 2, p. 1281.

[e] This referred to the ceiling limit the Edo Bakufu placed on overseas trade in +1685 to help curb the increased outflow of gold and silver that they expected to accompany the sudden arrival of fleets of Chinese vessels following the rescission of the ban on Chinese trading with foreign countries.

refer to sugarcane, and not to sugar palms. In view of the fact that the Chinese took their technology to the Philippines in the late +16th century, and Vietnam during the +17th century, I posit an initial transfer to Siam in the early +17th century. The principal reason being that the same incentives for the sale of sugar on the intra-Asian market that prompted contemporary Chinese activities in the Philippines and Vietnam also applied for Siam. Unfortunately, we have no information on sugar exports from Siam during the +18th century, and can only conclude that production must have halted, either for reasons related to domestic politics, or perhaps due to competition from other South-East Asian producers such as Vietnam.

Evidence concerning the second transfer was very solid. Dr Jean Gerard Koenig, a pupil of Linnaeus, who visited Siam in +1779 reported sugarcane but no sugar making.[a] It would seem that Siam manufactured no sugar at the time of Koenig for John Crawfurd, who visited the country in 1822 and left the following account of the origin of sugar manufacturing there:[b]

> The sugarcane has been known in Siam, as in other parts of India, time out of mind; but its culture, to useful and extensive purposes, does not date beyond twelve years before the period of our visit to the country, and originated in the industry and enterprise of the Chinese settlers, encouraged by some liberal concessions yielded to or extorted by them at the time from the Siamese Government. The result, in the year 1822, was a production of sugar, generally the whitest and best in India, to the extent of above 60,000 piculs, or above eight millions of pounds, exported to China, the western parts of Hindostan, Persia, Arabia, and Europe. The districts in which the sugar-cane is raised are Bam-pa-soi, La-kon-chai-se, Bang-kong, and Pe-triu, all within the fertile valley of the Menam. The cane is planted in the seventh month, or June; cut in the first month, or December; and sugar is produced in the market of Bangkok in the second month or January. The cultivators of the cane are always Siamese; but the manufacturers of the sugar invariably Chinese.

Crawfurd, blissfully unaware of Chinese activities in the +17th century, put the beginning of sugar production in Siam by the Chinese at about +1810. Once again we find the recurring pattern of the division of labour between the local people and the Chinese; it is the Siamese that cultivate the sugarcane, and the Chinese that make the sugar.[c]

Sugar making first commenced in the valley of the Menam river, or the Chao Phraya as the Thais affectionately call it, probably in the vicinity of Bangkok where large numbers of Chinese resided. Bishop Pallegoix, the French mentor to King Mongkut or Rama IV (r. 1851 to 1868) who arrived in the country in

[a] Koenig (1), p. 175. Koenig remarked that 'the grazing places, which lay close to the Governor's house, were mostly burnt down, and consisted of a kind of sugar-cane, which grew very high, had broad leaves and a very narrow panicles, and stood about as high as one or one and third men'.

[b] Crawfurd (1), p. 422.

[c] Burney ((1), vol. 2, pt 4, p. 101) wrote concerning sugar production in Siam, 'The Chinese are the sole manufacturers and the produce may be increased to any amount.'

1830, left a very intriguing account of a sugar mill run by a Chinese Christian with whom he stayed for a few days in the town of Pëtriu:[a]

> The whole province, which is an immense plain, consists of rice, gardens and sugarcane plantations. It has about twenty sugar mills all owned by Chinese. I lodged for some days with a Chinese Christian, the manager of a sugar mill of the kind that I am able to make a short description. On the bank of the river there are two or three piles or pieces of wood which are elevated to a height of fifteen to twenty metres; on the side we find a round shed where two buffaloes are turning in opposite directions two large cylinders of wood and iron which crush the cane; the juice collects in a tank made of masonry. Right behind is an enormous brick furnace which resembles a tower. In the upper part of the furnace are three large bars of iron on which lie three enormous pans enclosed in the same masonry. In the pans with the help of a fire of Hades the sugarcane juice is evaporated where after appropriate boiling it is poured into clay cones. The next day the molasses is drained and [the massecuite] purified with wet clay, and results in a very white cassonade. The reboiling of molasses and skimmings produces a good quantity of brown sugar. Finally the molasses is taken for making *arak* or mixed with lime for building [i.e. as mortar].
>
> The tanks of molasses are in the open air; lizards, rats and toads come to find their death there, and pickle themselves in large quantities. Two large sheds over fifty metres [long] each suffice not only for all the manufacturing equipment, but also to house the two hundred workers which are employed.

This was a most interesting application of *Thien Kung Khai Wu* technology, albeit with some modification. The clover-leaf arrangement of the boiling pans came straight out of the book, but the iron coating of the wooden rollers was an innovation. As in the Philippines, operators drained massecuite in cones and clayed after a single boiling, but the Chinese in Siam conducted the whole operation in a single factory, whereas their counterparts in the Philippines travelled the countryside of Luzon collecting the cones (*pilones*) for claying in Manila. In Siam the Chinese undertook the whole process in a single installation because they were free from the feudal restraints imposed on the whole Siamese working population under the *sakdina* system,[b] and could operate mills themselves in the countryside. I have no evidence of mills with as many as two hundred workers for China, the largest on Taiwan only employed about thirty-four people. Perhaps the lack of competition from indigenes, restricted from engaging in commercial ventures anyway, allowed enterprising Chinese with capital and the right social connections to organise production on larger scales than ever possible in the homeland. The 19th-century Siamese mills demonstrated that *Thien Kung Khai Wu* technology, though only applied for relatively small units of production in China, could accommodate large volumes of production if suitable conditions prevailed.

Since the *sakdina* feudal system prevented Siamese from acquiring sugar-making skills and technology, Chinese had to secure artisans and labourers from the

[a] Pallegoix (1), vol. 1, pp. 80–2.
[b] For the *sakdina* system see Suehiro (1), pp. 36–7.

ranks of their own countrymen. It is no exaggeration to say that this ethnic division of labour, as well as the exceptionally large numbers of Chinese workers in Siam, made possible the huge increase in Chinese-style sugar production. Crawfurd reported that the adult Chinese male population in Bangkok during the early 1820s numbered 31,000, and that a conservative estimate of the total Chinese population, mainly male, in Siam amounted to 100,000.[a] Despite the speed with which Chinese males intermarried with Siamese women,[b] the recentness of assimilation, and the tenacity of the Chinese, ensured that they maintained control over sugar production well into the 20th century. The Siamese court policy of encouraging the Chinese to engage in commercial endeavours, along with their support of Chinese control over foreign trade, also contributed to the continuation of this situation.[c] The Siamese monarch profited from the sugar trade by collecting inland and export duties on it, and ordered the Chinese to provide him, and some chosen officials, with a certain quantity of sugar below market price each year.[d]

The Chinese in Siam manufactured some of the best-quality sugars in Asia during the early 1820s according to John Crawfurd, who commented that, 'it is equal in quality to the best sugars of Bengal, which are in very small quantity, and much superior to the generality of the produce of that country'.[e] Sugar was so plentiful in Bangkok during the mid-1820s that it served as a major article of barter in trade with foreigners;[f] it became a staple Siamese export in the trade between Siam and the different countries of the Malayan Archipelago which increased greatly after the foundation of Singapore.[g] Crawfurd also noted that Siamese sugar found markets outside of the East Asian and South-East Asian regions, and was shipped as far off as the western parts of India, Persia, Arabia, and Europe;[h] during the mid-1820s sugar constituted the principal article exported from Siam by European and American trading ships.[i] It was even included amongst the gifts the Siamese tributary missions presented to the Viceroy of Canton and to the Chinese Emperor.[j] Crawfurd, on his visit in 1822, estimated the total amount of Siamese sugar available for export each year at over 60,000 piculs (approx. 3,600 tonnes), half of which, 30,000 piculs (approx. 1,800 tonnes), went to China.[k] By the early 1850s the total amount of sugar exported every year had risen to 250,000 piculs (approx. 15,000 tonnes),[l]

[a] Crawfurd (1), p. 450.
[b] *Ibid.*, pp. 449–50.
[c] For example for a discussion of the 1850s and 1860s, see Viraphol (1), pp. 234–5.
[d] Burney (1), vol. 2, pt 4, pp. 101–2 gave details for the mid-1820s. Burney portrayed the Chinese merchants as the ham in the sandwich, being squeezed by the Siamese farmers from below and the Siamese officials from above. Also see Viraphol (1) for the sugar monopoly.
[e] Crawfurd (1), p. 544.
[f] Burney (1), vol. 2, pt 4, p. 102.
[g] Crawfurd (1), p. 414.
[h] *Ibid.*, p. 422. He noted that Siamese sugar was exported to Europe via Singapore (p. 538).
[i] Burney (1), vol. 2, pt 4, p. 101.
[j] Crawfurd (1), pp. 408–9 and p. 544 for Singapore.
[k] *Ibid.*, pp. 413 and 422.
[l] Pallegoix (1), vol. 1, p. 327. The amount of cane sugar exported greatly exceeded the amount of palm sugar which Pallegoix recorded as 180,000 *piculs* (approx. 10,800 tonnes) *per annum*.

which indicated the considerable extent to which the Chinese expanded production.

(4) Case Studies of State-Induced Transfer

(i) *The Ryūkyū Kingdom*[1]

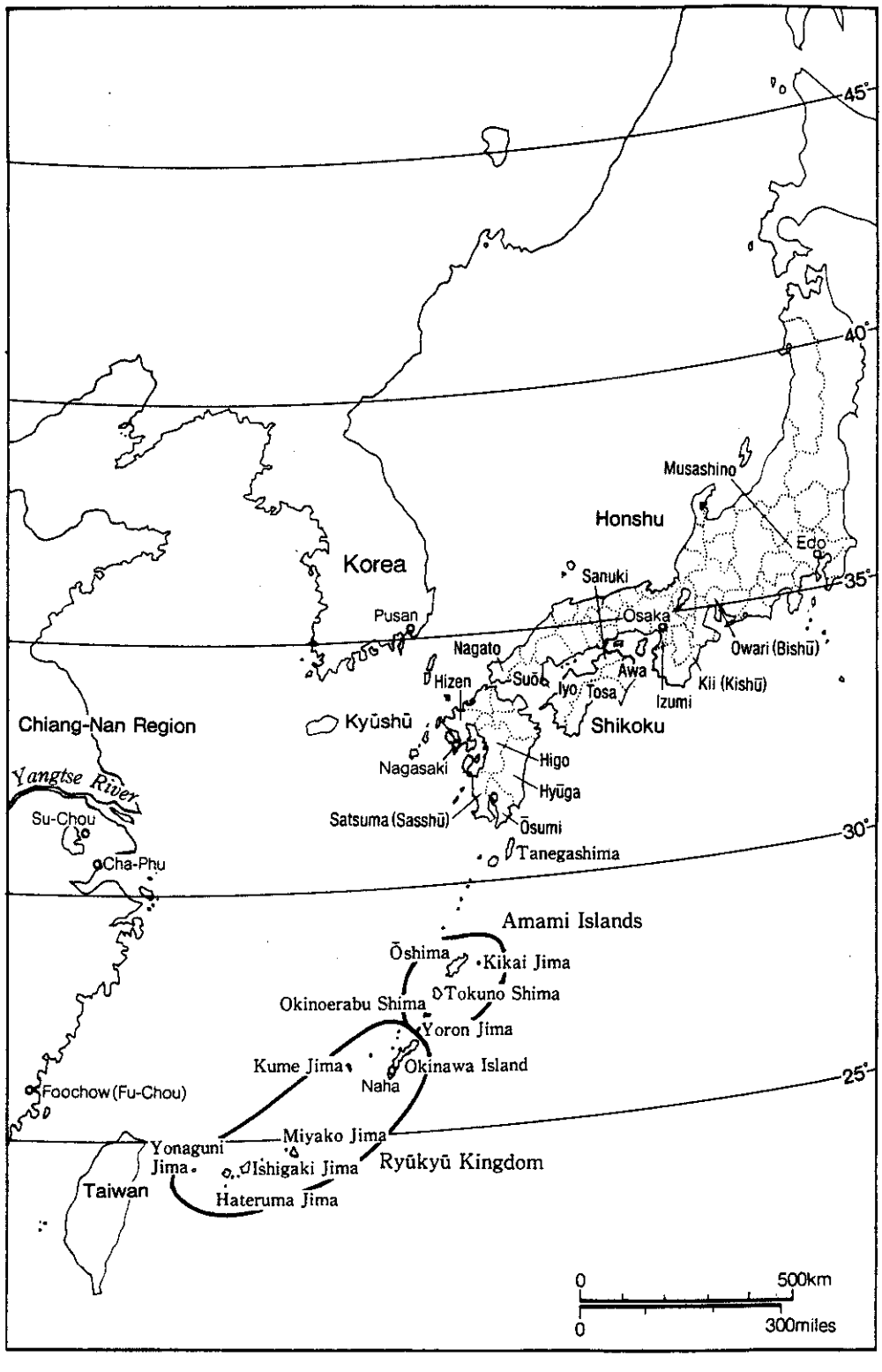
Ryūkyū[2], a small kingdom best known for the principal island of Okinawa[3], is located south of the Japanese island of Kyūshū[4], and north of Taiwan in the East China Sea. It maintained regular tributary relations with China throughout the Ming and Chhing periods. Tributary missions to China commenced in +1392 with Satto[5], King of Chung Shan State[6], and continued until 1879. As the most enterprising among the many States paying tribute to the Ming court, Ryūkyū sent by far the greatest number of missions, and for this reason received special treatment from China.[a] During the +15th and +16th centuries Ryūkyūan Kings used the tribute trade system and the prohibition on Chinese travelling overseas to their own advantage, to become principal exporters of Chinese products, such as porcelain, in a trading network extending from Korea and Japan in the North, to Malacca and Java in the South.[b] From the mid +16th century onwards, Ryūkyū began to lose its dominant position in South-East Asian commerce, mainly for the following reasons: first, the activities of Portuguese traders; second, the rise of Chinese merchants who engaged in illegal overseas trade; third, the relaxation on the ban on foreign trade by the Ming; and fourth, the advances of Japanese merchants.[c] After bondage to Satsuma[7], the southernmost *han*[8] of Japan, as a vassal State following an invasion in +1609, the kingdom lost most of the profits of the tribute trade with China to their Japanese overlords.[d]

We do not know exactly when or how sugarcane first arrived in the Ryūkyū Islands, but a Korean source, the *Ri Jo Sil Rok*[9] (The Veritable Records of the Ri Dynasty), recorded the introduction of a clone from Chiang-Nan in the lower Yangtse River delta area in the early +15th century. An entry for the 12th lunar month of +1429 carried the following statement by a Korean official:[e]

> The flavour of sugarcane (*kan-chê*[10]) is sweet and delicious. Eaten raw it relieves the thirst and hunger of people. It is also boiled to make sugar (*sha-thang*[11]). The Ryūkyū state obtained it from Chiang-Nan, and plants great amounts of it.

[a] Akiyama ((1), p. 552) listed the number of tribute missions sent to China during the Ming by tributary states in order of magnitude from the *Ming Shih*; Ryūkyū first with a total of 171, Annam second with 89, Champa fifth with 74, Siam sixth with 73, Malacca twelfth with 23 and Japan thirteenth with 19.
[b] Takara (1), pp. 92–3.
[c] *Ibid.*, pp. 224–6.
[d] Sakai (1).
[e] *Ri Jo Sil Rok*, vol. 7, p. 677.

[1] 琉球王國 [2] 琉球 [3] 沖繩 [4] 九州 [5] 察度
[6] 中山王 [7] 薩摩 [8] 藩 [9] 李朝實錄 [10] 甘蔗
[11] 沙糖



Map 5. Ryūkyū Kingdom, Amami Islands and selected Han domains in Tokugawa Japan.

Chinese sources indicated usage of sugarcane for brewing wine and as a fruit.[a] Depending on how you interpret it the Korean source may indicate that Ryūkyūans made some form of sugar prior to the introduction of the *Thien Kung Khai Wu* type of sugar technology, in +1623. A source of doubtful authenticity, the *Nagamine Ganso Yurai Ki*[1], related that a certain Nagamine Anji[2] (regional lord) learnt sugar making in Nan-Ching[3] during the Ching-Thai[4] period (+1450 to +1453), and after returning home spread the technology throughout the islands, and sold the sugar made in Japan at a profit.[b] Kadena Sōtoku[5] has suggested that Ming sugar technology was transferred and Ryūkyūans did make sugar before +1623,[c] but even if this source is considered valid, the sugar technology obtained from China most probably did not include the two-roller vertical mill, but the contemporary Chinese practice of chopping sugarcane into small pieces, for crushing in a mortar and pestle, or a pressing device, before submission to a diffusion process. In any case the art of sugar making seems to have been inadequate, or perhaps lost, as the Ryūkyūans positively sought its transfer.

Thien Kung Khai Wu technology did not arrive until the +17th century when it came in two stages. The first is documented in the history of the Ryūkyūs, the *Kyūyō*[6] of +1745, under an entry entitled, 'Ma Phing-Hêng[7] made black sugar (*hei-thang*[8]) for the first time in +1623';[d]

Ma Phing-Hêng (the Oyakata, Gima Shinjō[9])[e] was deeply concerned that Ryūkyū had sugarcane but did not know how to make sugar, and he sent people from Gima village[10] to Fukien [to study it]. It was only after they had learnt the method of making sugar that they [were able] to boil black sugar from the juice of sugarcane harvested at Gima's house. In the end [this method of sugar making] spread throughout the country.

Despite the brevity of description I agree with Nakahara Yoshitada[11] and Kinjō Isao[12] that the crushing apparatus was the two-roller vertical mill, even though this puts it fourteen years earlier than the first reference in the *Thien Kung Khai*

[a] *Hsing Chha Shêng Lan* of +1436, p. 8, mentioned brewing sugarcane juice to make wine (*niang kan-chê wei chiu*[13]), and the Chinese envoy, Chhên Khan[14] who came to invest the Ryūkyūan King in +1534 listed sugarcane wine as a fruit in his *Shih Liu Chhiu Lü*[15] along with bananas (*pa-chiao*[16]), pomegranates (*shih-liu*[17]), oranges (*chü*[18]) and persimmons (*shih*[19]). Kinjō ((*1*), pp. 43–4) speculated that the thirty-six surnames from Fukien (*Min jên san-shih-liu hsing*[20]) may have played a part in the introduction of sugarcane. He also suggested that the clone introduced may have been miscanthus cane (*Saccharum sinense*) as the word for sugarcane in the Ryūkyū dialect is *uji* which is written with the Chinese character for miscanthus (*ti*[21]). Ueno ((*1*), p. 64) claimed that the sugarcane in the Ryūkyū Islands came from China, and was one of the *yomitanzan*[22] (*Saccharum sinense*) clones.

[b] Kinjō (*2*), p. 14; Katsura (*1*), p. 14.

[c] Kadena (*1*), pp. 32–3 and 62–7.

[d] *Kyūyō*, item 273, p. 212.

[e] Ryūkyūan officials normally had Chinese and Japanese names. In this case Ma Phing-Hêng is the Chinese name of Gima Shinjō.

[1] 長嶺元祖由來記 [2] 長嶺按司 [3] 南京 [4] 景泰
[5] 嘉手納宗德 [6] 球陽 [7] 麻平衡 [8] 黑糖 [9] 儀間眞常
[10] 儀間村 [11] 仲原善忠 [12] 金城功 [13] 釀甘蔗爲酒 [14] 陳侃
[15] 使琉球錄 [16] 芭蕉 [17] 石榴 [18] 橘 [19] 柿
[20] 閩人三十六姓 [21] 荻 [22] 讀谷山

Wu of +1637.[a] The reasons are as follows: first, the Chinese two-roller mill arrived in the Philippines before +1613; second, the two- roller mill had to be introduced before a three-roller mill could be innovated from it (discussed below p. 450); third, the two-roller mill, which appeared in China during the late +16th century if not earlier, was the most logical of the available choices – it processed greater amounts of sugarcane more speedily than possible under the press/diffusion techniques described in gazetteers of the first half of the +16th century, and the *Nung Chêng Chhüan Shu*[1] of +1639. In short it would have been better suited to increasing production levels, and easier to operate into the bargain.

The transfer was effected by the efforts of an individual, Gima Shinjō, who displayed deep interest in adopting new technology to promote the welfare of the Ryūkyūan people. Previous experience had taught him the advantages to be gained from such transfers as he had played a part in promoting the local diffusion of the sweet potato, which a native Ryūkyūan, Noguni Sōkan[2], brought from south China in +1605.[b] Most importantly Gima was not a mere commoner, but held the rank of *Oyakata*[3] or elder. It was precisely this grade of official that headed the Ryūkyūan missions to China, which allows us to speculate that he might have pulled some strings to send indigenes to Fukien with one of the tribute missions.

The second stage encompassed the introduction of the method of boiling white sugar and sugar candy. This is documented in the *Kyūyō* under an entry entitled, 'Lu Tê-Hsien[4] went to Fukien to learn the art [of making] white sugar (*pai thang*[5]), sugar candy (*ping thang*[6]) and lacquer utensils in +1663':[c]

Lu Tê-Hsien, (the *pēchin*[7], Taketomi Shigesato[8]), received orders to travel to Fukien with the Congratulatory Envoy (*Chhing-ho shih*[9]), proceed to the Nan-Ku Shan[10] area to seek good teachers, completely master their instructions and transmit [to Ryūkyū] the arts of boiling white sugar and sugar candy, as well as the method of painting black, red and pear colour backgrounds with vermilion and to gild them with gold and silver (*chu thu hei chhih li ti nai chih tsao chin yin po teng chih fa*[11]). After returning home, he taught the head of the Mother-of-Pearl artisans the method of gilding gold and silver and making lacquer objects. In addition, he instructed the people of the Urasoe[12] area in the art of making white sugar.

Again the transmitter of the technology, Taketomi Shigesato, was a person of rank *pēchin*, a junior elder, the fourth rank below the King. The impetus for sending an official to learn advanced sugar technology came from the institution of a sugar monopoly by the royal government in the mid +17th century.

[a] Nakahara (*1*), pp. 34–5 and Kinjō (*1*), pp. 276–81.
[b] *Kyūyō*, item 244, p. 206. The sweet potato rapidly became a major food crop after its introduction.
[c] *Kyūyō*, item, 349, pp. 221–2.

[1] 農政全書 [2] 野國總官 [3] 親方 [4] 陸得先 [5] 白糖
[6] 氷糖 [7] 親雲上 [8] 武富重隣 [9] 慶賀使 [10] 南鼓山
[11] 朱塗黑赤梨地乃製造金銀箔等之法 [12] 浦添郡

The royal government allocated the profits gained from the sale of sugar and turmeric dye (*ukon*[1]) for the repayment of a loan from Satsuma incurred in +1646.[a] Government control over sugar production gradually increased, limiting the amount of land on which sugarcane could be grown in the +1690s, to prevent a fall in sugar prices due to oversupply, and at the same time ensure adequate levels of food production.[b] It was in the context of such government direction, and before the restrictions on the area of sugarcane cultivation, that a Ryūkyūan made an improvement to the two-roller vertical Chinese mill.

In the *Kyūyō* under an entry for +1671 reading: 'constructing a three cylinder (*chu*[2]) mill to make sugar for the first time and spreading it throughout the country', we find:[c]

> Chên Yang-Hsin[3] (the *chikudon pēchin*[4], Makiya Sanekiyo[5]) of Shuri[6] observing that the sugar mill (*thang chhê*[7]) only used two rollers (*chu*[2]) put all his energy into making a three-roller sugar mill (*san chu thang chhê*[8]). He taught people in the local area about it, and in the present age it is employed all over the country. The three-roller sugar mill began with this.

This constituted a unique case of an independent innovation within an area of strong Chinese influence. This three-roller vertical mill was later transferred to the Amami Islands, and probably Japan. Though we have evidence for the three-roller mill in a +1613 Spanish manuscript drawing for Brazil, it has not been recorded for China, or even for overseas Chinese before the mid-19th century. Once again the innovator, Makiya Sanekiyo, was a ranked state official, and, together with the other two cases explained above, this indicated a pattern of impetus for the introduction of new technology and native innovation among members of the ranked official classes. This pattern stood in great contrast to the attitudes of bureaucrats in China, and we shall meet it again in the Amami Islands and Japan.

Yet, in comparison with subsequent developments in the Amami Islands and Japan little innovation took place in sugar milling in the Ryūkyū islands after +1671, and the changeover from wooden to stone rollers did not begin until 1854. Despite encouragement from the royal government, the low price of wood and high cost of stone, prevented their rapid diffusion. Iron rollers were only introduced in 1882, far later than in the Amami Islands.[d] The reason for this difference is probably that the Ryūkyū State was not forced by Satsuma to increase sugar production to the same extent as the Amami Islands. To Satsuma, the foreign trade that it conducted through the Ryūkyūs, furnished an even more lucrative source of revenue than impositions placed on local

[a] Kinjō (*2*), p. 16.
[b] *Ibid.* pp. 16–18.
[c] *Kyūyō*, item 450, p. 232.
[d] Kinjō (*1*), pp. 35–40.

[1] 鬱金 [2] 柱 [3] 眞養心 [4] 筑登之親雲上 [5] 眞喜屋實清
[6] 首里 [7] 糖車 [8] 三柱糖車

resources. Satsuma *daimyō*[1] monopolised foreign trade and their *han* officials supervised it very closely.[a]

The introduction of Chinese sugar making at the hands of indigenes in +1623, seems surprisingly late considering the fact that Chinese immigrants provided Ryūkyūan Kings with essential skills, and technical expertise not available in the islands from the late +14th century onwards. Chinese served as shipbuilders, captains, navigators and interpreters on the trading ships that sailed to China and South-East Asia from the +14th to the +16th centuries. In addition, they acted as official interpreters and composers of diplomatic documents in classical Chinese for tribute missions to China until the late 19th century.[b] This group of technicians, originally dubbed the thirty-six surnames from Fukien (*Min jên san-shih-liu hsing*[2]), reputedly arrived in the islands during the reign of Satto[3] (+1350 to +1396), the King of Chung Shan[4]. Thirty-six was merely figurative for a large number of Chinese people with different surnames.[c] Accorded a special status, their descendants resided in a single village from the late +14th century until the +19th century. Initially known as the Chinese settlement (*thang ying*[5] and *thang jung*[6]), and later as Kume mura[7] (Kuninra or Kuninda), it was set apart from the residences of ordinary Ryūkyūans in Naha.[8] Depleted in numbers by the late +16th century, many of them could no longer speak Chinese, and the level of navigational skills had fallen. The Chinese community was revived with the acceptance of new members such as Juan Kuo[9] and Mao Kuo-Ting[10] in +1609, as well as the incorporation of native Ryūkyūans proficient in Chinese. This measure along with the fact that between +1481 and +1798 the State only permitted the residents of the Chinese village, Kume mura, to study in China, as both private and Ryūkyūan government sponsored students (*kanjō*[11] or *kuan-shêng*[11]). This policy enabled the village to retain its special skills and status over the five-hundred-year period of its existence.[d] At first, the residents adhered to a Chinese life style, but later adopted Ryūkyūan customs especially the local *coiffure*, called *Katakashira*[12] or *Katanchobi*[12], after the Manchus imposed the pig tail (*pien-fa*[13]) on males in China during the +17th century.

There seem to be three reasons why these Chinese residents did not transmit sugar technology to the Ryūkyūs before Gima Shinjō in +1623. First, male Chi-

[a] Sakai (1), pp. 131–2.

[b] Takara (1), pp. 54–5 and 137–8.

[c] Chinese and Ryūkyūan sources indicate that the first Ming Emperor, Hung-Wu (r. +1368 to +1398) bestowed the people of the thirty-six surnames from Fukien on the Ryūkyūan King, though there was some variation as to the actual date of their arrival, see Kyūyō Kenkyūkai (1), pp. 59–61. I agree with Takara ((1), pp. 54–5) that they probably immigrated as individuals or small groups arriving in different batches rather than all coming at once in a large group.

[d] Kyūyō Kenkyūkai (1), pp. 59–63.

[1] 大名 [2] 閩人三十六姓 [3] 察度 [4] 中山王 [5] 唐營
[6] 唐榮 [7] 久米村 [8] 那覇 [9] 阮國 [10] 毛國鼎
[11] 官生 [12] 欹髻 [13] 辮髮

nese villagers above the age of fifteen received regular salaries from the Ryūkyūan King as officials of the State, so their interests did not extend to private economic enterprise as did those of the Chinese in South-East Asia.[a] Even the Ryūkyūan government-sponsored students, and the private ones as well, had no incentive to learn about sugar technology, since their studies aimed to groom them for performing duties as Ryūkyūan government officials in the tribute trade. Moreover, even if they had the inclination, Peking, where many of them went, was not a sugar-manufacturing area. Second, the Ryūkyūan monarchy did not need to promote agro-industrial production to generate new sources of income before the Satsuma invasion of +1609. It was only after the decline of the Kingdom's former leading position in the trade between East and South-East Asia, and the imposition of a tribute tax on the Ryūkyūan King by Satsuma that it became necessary to search for other sources of income to meet these new fiscal demands. Third, the double-roller sugar mill was not available in China for transfer overseas before the second half of the +16th century, and this corresponded to a period of decline in the Chinese community at Kume mura.

(ii) *The Amami Islands*[1]

The Ryūkyū Kingdom[2] originally included within its domain the five islands of Oshima[3], Kikaijima[4], Tokunoshima[5], Okinoerabushima[6], and Yoronjima[7], now known as the Amami Islands. Satsuma *han* assumed direct control over these islands following the invasion of +1609, and the new rulers made deliberate efforts to break the islanders' strong cultural and religious ties with their former potentate, and assimilate them into Satsuma culture. They employed two devious methods to undermine the authority of the Ryūkyūan court in the eyes of Amami commoners: first, by the confiscation and burning of genealogical records in +1706; second, by removing status distinctions between officials and commoners – high officials of the Amami Islands, who formerly held investments from the Ryūkyūan King, lost their rights to respect from the common people, as a privileged group.[b]

Scholars have debated the issue of when sugar-making technology first entered the islands. Tradition held that Sunao Kawachi[8], a native of Oshima, introduced the two-roller vertical sugar mill from China in +1610 thirteen years earlier than Gima Shinjō[9] in the Ryūkyūs. But this theory, based on an oral tradition not put down in writing until 1877, has been shown to be invalid.[c] Two other facts also rendered such an early transfer most unlikely. First, the

[a] Maeda, Misumi & Minamoto (*1*), p. 163.
[b] Matsushita (*1*), pp. 34–58 and Sakai (*1*), pp. 127–9.
[c] Ueno (*1*), p. 63.

[1] 奄美郡島　[2] 琉球王國　[3] 大島　[4] 喜界島　[5] 徳之島
[6] 沖ノ永良部島　[7] 與論島　[8] 直川智　[9] 儀間直常

earliest record was with the *Yokome*[1] (Inspector) of Yakinai magiri[2], Kawachi[3], who grew sugarcane and made sugar on Oshima upon returning from the Ryūkyūs after a two-year visit in +1688 to +1689.[a] Second, Satsuma *han* appointed a Sugarcane Inspector (*kibi kenja*[4]) on Oshima and Kikaijima in +1695 to supervise production indicating that sugar making only commenced around this time on a significant scale.[b] The number of sugarcane inspecting officials appointed to oversee all aspects of sugar production, from cultivation to final boiling, increased as output rose gradually during the +18th century. This trend culminated in the conversion of the rice tax to a payment in sugar in +1745, which severely restricted rice cultivation and encouraged sugarcane monoculture.[c]

The technology, which eventually arrived, probably in the +1680s, included the three-roller vertical mill developed in the Ryūkyūs and the Chinese three-pan boiling method. The three-roller vertical mill must have been introduced at this time for Tabata Sabuni[5] (+1678 to +1764) to have devised a method of driving it with water power in +1717.[d] As can be seen from Figs. 86 and 87, the three rollers had to be mounted horizontally, to harness it to a water wheel; a diversion from the standard Chinese engineering practice of positioning rollers vertically. Though inadequate supplies of water in the crushing season prevented the extensive use of hydraulically powered mills, they reputedly ground more than twice as much juice as animal-driven ones. Nagoya Sagenta[6], a high-ranking Satsuma samurai exiled to Oshima for five years between 1850 and 1855, related that in a day a water-powered mill crushed 5 *koku*[7] (900 litres) of cane juice, while an animal-driven mill only processed a little more than 2 *koku* (360 litres).[e] Later the Japanese adopted the idea of water-powered sugar mills, and devised a variety of gearing arrangements as illustrated in the *Satō Seisaku Ki*[8] of +1797 by Kimura Yoshiyuki[9] (see Fig. 95).

The next development was the replacement of wooden with iron-capped rollers by an indigenous innovator, Kashiwa Yūto[10], in 1808. Kashiwa Yūto, also a *Kibi Yokome*[11] (cane inspector), experimented with seven- and five-roller mills, which he craftily tried to drive utilising the instinctive attraction of male to female by having a stallion follow a mare around the race. This proved unsuccessful, but he ended up devising a mill with iron-coated wooden rollers, an improvement because the rollers did not wear out as fast and could be adjusted with greater precision, thus giving better extraction.[f] But they did not spread

[a] *Ibid.* p. 64.
[b] Matsushita (1), p. 63.
[c] Matsushita (1), pp. 106–7.
[d] Ueno (1), pp. 64–6.
[e] See Shō (1), p. 293 and Nagoya (1), p. 65 for the crushing rate.
[f] Shō (1), pp. 292–3. Kashiwa Yūto experimented with multiple-roller mills 22 years before these mills emerged in Europe in 1840. The first European mill (a six-roller mill) appeared in British patent No. 8731 of 1840 by James Robertson, acting for unnamed parties in Mauritius and Réunion, see Deerr (1), p. 542. Kashiwa Yūto must have been aware of the poor extraction of roller mills well before engineers in the West

(*cont.*)

[1] 横目 [2] 屋喜内間切 [3] 嘉和知 [4] 黍検者 [5] 田畑佐文仁
[6] 名越左源太 [7] 石 [8] 砂糖製作記 [9] 木村喜之 [10] 柏有度
[11] 黍横目

rapidly on Oshima as Nagoya Sagenta mentioned that by c. 1850, they only accounted for over half of the mills. At this time a number of wooden mills still remained in operation, but Nagoya specially remarked on the shortage of oak and other timber suitable for constructing rollers.[a]

Nagoya Sagenta wrote an account of sugar-manufacturing technology on Oshima during the first half of the 1850s in his celebrated *Nantō Zatsuwa*[1].[b]

In winter from the eleventh lunar month the roller mills (*kuruma*[2]) are set up and driven by cattle and horses. Waterwheels (*suisha*[3]) are installed with a set of three rollers (*kuruma*) at the one place. When two big stalks of sugarcane are inserted between the three rollers, the middle roller turns to the right[c] while the left and right side rollers rotate to the left. The three rollers all revolve together. The expressed sugarcane juice is poured into a container (*tango*[4]), lime (*sekkai*[5]) mixed in and boiled in three pans (*nabe*[6]) between which the syrup is moved. Later it is shifted to a single pan in which it is cooled by stirring with a pole to form top-class sugar.

The fine points of the operation (*kagen*[7]) vary with the practices of each household. An average of the results from boiling over the years shows that a yield of 7 *kin*[8] (4.2 kilos) of sugar [*kurozatō*[9]] from 1 *tō* (18 litres) of sugarcane juice is the best, 5.5 to 6 *kin* (3.3–3.6 kilos) is medium and 4.5 *kin* (2.7 kilos) is low.[d]

In this connection it is interesting to recall that Oshima manufactured white sugar before the Japanese mastered the art. A Satsuma *han* official, Zushizaki Ryōsuke[10] who assumed a post on Oshima in +1767, reported white sugar made for family consumption. Satsuma *han* tried to enforce greater production in +1789, but this move proved unsuccessful. The manufacture of significant amounts of white sugar did not commence for shipping to the Japanese mainland islands for sale on the domestic market until after 1801.[e]

Satsuma *han* implemented a cruel and unjust monopoly in 1829, which remained in force until 1873, and totally banned the private sale of sugar by Amami peasants. From 1837 onwards, all sugar manufactured in the islands had to be delivered to the *han* storehouses, and after deducting an amount as tax, peasants received bills (*tegata*[11]) as payment for the remaining sugar. The *han* forced peasants to buy daily necessities that it had purchased in Osaka after

Footnotes to page 453 (*cont.*)

Indies. Deerr ((1), p. 546) wrote that the French undertook the first systematic investigation into the extraction of roller mills which culminated in a report of 1840.

[a] Nagoya (*1*), p. 65.

[b] *Ibid.*

[c] The printed text in Nagoya (*1*), p. 65 has the word *ishi*[12] (stone), but from context this must be a mistake for *migi*[13] (right).

[d] 18 litres of juice at 1.1 specific gravity was 19.8 kilos of juice which equalled 39.6 kilos of sugarcane at 50% extraction. The yield of *kurozatō* calculated by the formula 4.2 × 100/39.6 would be 10.6% at the best, which was about the sucrose % cane in these areas. The top yields were satisfactory, but the low yields at 6.8% were poor.

[e] Matsushita (*1*), pp. 142–3.

[1] 南島雜話 [2] 車 [3] 水車 [4] 丹荷 [5] 石灰
[6] 鍋 [7] 加減 [8] 斤 [9] 黑糖 [10] 圖師崎眞助
[11] 手形 [12] 石 [13] 右

selling the sugar, with these bills. Though only receiving less than one third of the Osaka price for their sugar, they had to pay many times the original purchase value for the Osaka goods. Satsuma *han* took advantage of increased price differentials, as well as the forced cultivation of sugarcane, to generate income to repay its enormous *han* debt. The aim of tightening control over sugar production in Amami, was to compete more effectively on the domestic Japanese sugar market, against sugar made by rival *han* on the island of Shikoku and the east coast of Honshū in the early +19th century.[a] Needless to say, this wrought detrimental effects on local society. Under the sugar monopoly, an estimated 35 per cent of the islanders fell into bondage, and the resulting stratification destroyed the rural community (*nōson kyōdōtai*[1]). This has led more than one scholar to describe sugar production in the Amami Islands as the management of sugar plantations by feudal power under colonial rule.[b]

Here, as in the Ryūkyū Kingdom, the innovators hailed from the ranks of local officials; both Tabata Sabuni and Kashiwa Yūto served as *Kibi Yokome* (cane inspectors). Tabata, one of the first to be appointed in +1698, was eventually rewarded by Satsuma *han* for his distinguished service in opening up new land for agricultural cultivation, being the first native of Oshima to be made a *gōshi*[2].[c] The control local officials exercised over production allowed them to encourage the spread of new technology, but the implementation of the complete sugar monopoly seems to have stifled any attempt at further innovation after 1830.

(iii) *Japan*

After +1636, the Bakufu[3] restricted foreign trade to Chinese and Dutch merchants at Nagasaki[4], and the Koreans at Pusan[5]. As part of their claustration policy, they later placed annual quotas on sugar imports, but this measure failed to achieve its stated purpose of checking the large outflow of gold, silver and copper from the country in payment for sugar. Sugar imports exhibited great fluctuation between +1637 and +1683, from a low of nil in +1643 to a high of just under 4 million *kin* (approx. 2,400 tonnes) in +1662;[d] prior to the Shōtoku[6] period (+1711 to +1715) annual sugar imports were restricted to 3.5 million *kin* (2,100 tonnes), and increased thereafter to 4.3 million *kin* (2,580 tonnes).[e] A large market for the imported article evidently existed, especially in the urban areas, where it was used in confectionery and increasingly as a

[a] Oka (*1*), p. 419.
[b] Oyama Ringorō (1), pp. 11–12.
[c] Ueno (*1*), p. 66.
[d] Innes (1), p. 506, table 32.
[e] Higuchi (*2*), p. 309.

[1] 農村共同體 [2] 郷士 [3] 幕府 [4] 長崎 [5] 釜山
[6] 正徳

condiment during the +17th and 18th centuries.[a] One solution to the problem, realised quite early, called for import substitution. As early as +1697 the agriculturalist, Miyazaki Yasusada[1] (+1623 to +1697), suggested in his *Nōgyō Zensho*[2] (Collected Writings on Agriculture) that the outflow of specie could be effectively curbed, and the wealth of the country enhanced, by cultivating sugarcane and making sugar in the warmer coastal areas. Miyazaki also cautioned that this activity was a task for the State, and not the commoner if quick results were desired,[b] and indeed all attempts at sugarcane cultivation during the +17th century seem to have ended in failure; the *Honchō Shokkan*[3] (Japanese Alimentotherapy), also of +1697, mentioned that clones of sugarcane recently introduced from China, Korea and Ryūkyū had not been successfully grown in Japan.[c] Due to the high latitude and cold winters, sugar production in Japan could only really commence and be maintained with strong encouragement and protection from the Bakufu and the *daimyō*. Yet it was not until +1726, when the eighth Shōgun, Yoshimune[4], personally ordered the study of sugar making that the Bakufu began actively to adopt measures to curtail the outflow of specie in payment for sugar imports by encouraging domestic sugar production.

Since the Japanese had never grown sugarcane in the past, their first task was to obtain knowledge of cane growing and sugar-making methods. There were two sources from which the Japanese could learn at that time: China and the Amami and Ryūkyū Islands. A third possible source appeared in the preface to the *Satō Seisaku Kō*[5] of +1797 in which Kimura Yoshiyuki[6] attributed Yasuda

[a] Unless otherwise noted the outline presented here and below on sugar in Japan during the +17th and +18th centuries was based on Higuchi (*2*), pp. 73–110. For an account of the role of foreign trade in the domestic economy of Japan during the +17th century see Innes (1).

[b] *Nōgyō Zensho*, pp. 391–2.

[c] Shimada (1), vol. 2, p. 139. *Nōgyō Zensho*, p. 391 also stated that sugarcane clones had been brought to Satsuma in recent years. The earliest reference to the import of sugarcane to Japan for the purposes of research dates back to the eighth lunar month of +1667 when vessels from Batavia and Patani arrived with three stalks of sugarcane (*satōdake*[7]). This introduction followed an order by Tokugawa Mitsukuni[8] (+1628 to +1700), and these ships carried three monkeys, three musk cats (*shakō neko*[9]) three longan trees, three litchi trees, and 130 *momme*[10] (approx. 487 grams) of arsenic (*shinseki*[11]) as well as the sugarcane stalks, see *Tōtsūji Kaisho Nichiroku*, vol. 1, p. 89 and Innes (1), p. 301. Also, a notice posted in the tenth lunar month of +1667 prompted the Chinese to bring to Japan, (1) people well acquainted with various types of medicines, (2) the seedlings of medicinal plants, and (3) machines for processing drugs and medicinal oils. Tokugawa Mitsukuni repeated this request in +1668 and +1670, and instructed the interpreters to issue it each year. The Chinese responded by furnishing the Japanese with two seedlings of medlar (*kou chhi*[12] *Lycium chinense* Mill., R 115), one of China root (*sankirai*[13] the Japanese appellation for *thu fu ling*[14]; *Heterosmilax japonica* Kth, R680) and ten of the betel palm (*pin lang*[15], *Areca catechu*, willd, R 713) in +1669. In the following year they landed *China root* seedlings, and a Tung-Ning[16] (Taiwanese) vessel also arrived at Nagasaki with one seedling of *Polygonum multiflorum* Th. (*ho shou wu*[17], R 576) and two of honeysuckle flowers (*chin yin hua*[18]: *Lonicera japanica* Th., R 75). Most of these medicinal plants were planted in the premises of officials, but we do not know anything of their success, see *Tōtsūji Kaisho Nichiroku*, vol. 1, pp. 90, 91, 93.

[1] 宮崎安貞 [2] 農業全書 [3] 本朝食鑑 [4] 吉宗 [5] 砂糖製作記
[6] 木村喜之 [7] 砂糖竹 [8] 徳川光圀 [9] 麝香猫 [10] 匁
[11] 信石 [12] 枸杞 [13] 山帰来 [14] 土茯苓 [15] 檳榔
[16] 東寧 [17] 何首烏 [18] 金銀花

Tai[1] with learning from the Dutch at Nagasaki, and bringing the method back to Kii[2] (Wakayama[3] prefecture).[a] However, as Higuchi remarked, contemporaries had the habit of referring to all new technology that entered Japan through Nagasaki as Dutch. In addition, as the methods Kimura outlined in his work, which he claimed derived from Yasuda, were basically the same as those given in the account of Hiraga Gennai[4] in his *Butsurui Hinshitsu*[5] of +1763, which were unquestionably Chinese, we can assume a Chinese origin.[b] The only reservation about this is the illustrations of three-roller mills which decidedly were not Chinese, as explained earlier.

About +1726 Shōgun Yoshimune specially appointed people to study Chinese sugar technology by referring to the *Thien Kung Khai Wu*[6], *Min Shu*[7] and other Chinese works, as well as ordering interviews with Chinese merchants at Nagasaki. Apart from Bakufu-appointed officials and technicians, other participants included doctors and agriculturalists such as Nagatomi Dokushōan[8] (+1732 to +1766), Hiraga Gennai (+1728 to +1779), along with interested people like Yasuda Tai and Yoshiemon[9] who learnt and spread the art of sugar making independently of the Bakufu.[c] In spite of official support and all this experimental activity, it took the Japanese quite a while to apply the technology effectively for we find that a Bakufu-appointed technician, such as Ikegami Tarōzaemon[10] (+1718 to +1798), only succeeded in successfully cultivating sugarcane by about +1747. Moreover, he did not master sugar making until about +1768, despite having the assistance of the renowned Edo doctor and naturalist Tamura Genyū[11] (+1718 to +1776).[d] Ikegami only learnt to make white sugar by the An'ei[12] period (+1772 to +1780), and manufactured sugar candy (*hyōtō*[13]) for the first time in +1797 with the help of his son.[e] Nevertheless, Ikegami holds an important place because he sent technicians to *han* in south-western Japan to disseminate sugar-making technology. According to Katsura Masaki[14], he despatched 155 people between +1769 and 1802.[f]

The combined efforts of Bakufu-supported and independent technicians resulted in the diffusion of sugar technology over south-western Japan by about 1800, thus providing the technological pre-conditions necessary for the great expansion of sugar manufacture during the first seventy years of the 19th century. Domestic sugar production rose so much that after 1808, the Bakufu occasionally had to place restrictions on the amount of sugar on the Osaka[15] market,

[a] *Satō Seisaku Kī* p. 383. Higuchi ((*2*), p. 94) quoted the *Kii Koku Zoku Fudoki*[16] saying that Yasuda first made sugar in Kii in +1740.

[b] Higuchi (*2*), pp. 94–5.

[c] *Ibid.*, pp. 73–97.

[d] *Ibid.*, pp. 76–7 and Katsura (*1*), pp. 34–5.

[e] Higuchi (*2*), p. 84.

[f] Katsura (*1*), p. 38.

[1] 安田泰 [2] 紀伊 [3] 和歌山縣 [4] 平賀源內 [5] 物類品隲
[6] 天工開物 [7] 閩書 [8] 永富獨嘯庵 [9] 慶右衛門
[10] 池上太郎左衛門 [11] 田村元雄 [12] 安永 [13] 氷糖
[14] 桂眞幸 [15] 大阪 [16] 紀伊國續風土記

and in 1818 issued a prohibition against the cultivation of sugarcane on land suitable for growing rice. These measures seem to have exercised little effect as domestic production of sugar continued to grow. The earnings from the sale of sugar became a major source of revenue for some *han*, so important to them that they chose to ignore Bakufu regulations.[a] The most notable included first, Satsuma, which controlled black sugar (*kurozatō*) production in the Amami Islands and Ryūkyū Kingdom, and second, Sanuki[1] and Awa[2], located on the island of Shikoku[3], the largest producers of *sanbon*[4] white (a soft fine-grained white sugar).

The decentralised nature of feudal power allowed different *han* to promote and protect sugar production in their own domains. The tough financial straits many *daimyō* faced by the late +18th century greatly encouraged them to generate income by promoting production of sugar to overcome their monetary difficulties. Tough competition between sugar producing *han* ensued, and in the early 1840s it caused the price of sugar on the Osaka and Edo[5] markets to fall. Politically powerful Satsuma *han* felt acutely threatened, and secretly petitioned the Bakufu to take steps to reduce sugar production in other *han*, even demanding measures to halt the publication of a treatise on sugar technology entitled *Satō Seizō Sho*[6], by the renowned exponent of commercial agriculture Okura Nagatsune[7] (+1768 to +1860?). They seem to have succeeded as the treatise never appeared in print, even though the manuscript had been submitted to an Osaka publisher and advertisements issued in 1841.[b] As a matter of course, the main sugar-producing *han* always tried to prevent competitors learning about their sugar-making techniques.

It lies beyond the scope of this study to give a full account of the development of Japanese sugar technology, but I shall briefly show how they borrowed and innovated on roller mills and sugar refining.

Roller mills

A perusal of the manuscript account of observations by Tamura Genyū in his *Kansha Zōsei Den*[8] (A Record of Sugarcane [and Sugar] Manufacturing) of +1760, and comments by the eccentric botanist and playwright Hiraga Gennai in his *Butsurui Hinshitsu* of +1763 reveal considerable experimentation with both double- and triple-roller sugar mills some time in the late +1750s (see Fig. 114).[c] But how did these mills arrive in Japan? The double-roller mill obviously came from China. The information collected by Japanese officials from Chinese at Nagasaki in the ninth lunar month of +1726 recorded an animal-driven stone mill (*yung shih chhê shih niu thuo chhien*[9]). Officials, finding verbal explanations in-

[a] For Bakufu measures after +1808 see Oka (*2*), pp. 299–300.
[b] Oka (*1*), pp. 419–20.
[c] *Kansha Zōsei Den*, pp. 6a–8a and *Butsurui Hinshitsu*, Kan 6, p. 17b.

[1] 讃岐 [2] 阿波 [3] 四國 [4] 三盆白 [5] 江戸
[6] 砂糖製造書 [7] 大藏永常 [8] 甘蔗造製傳 [9] 用石車使牛拖牽

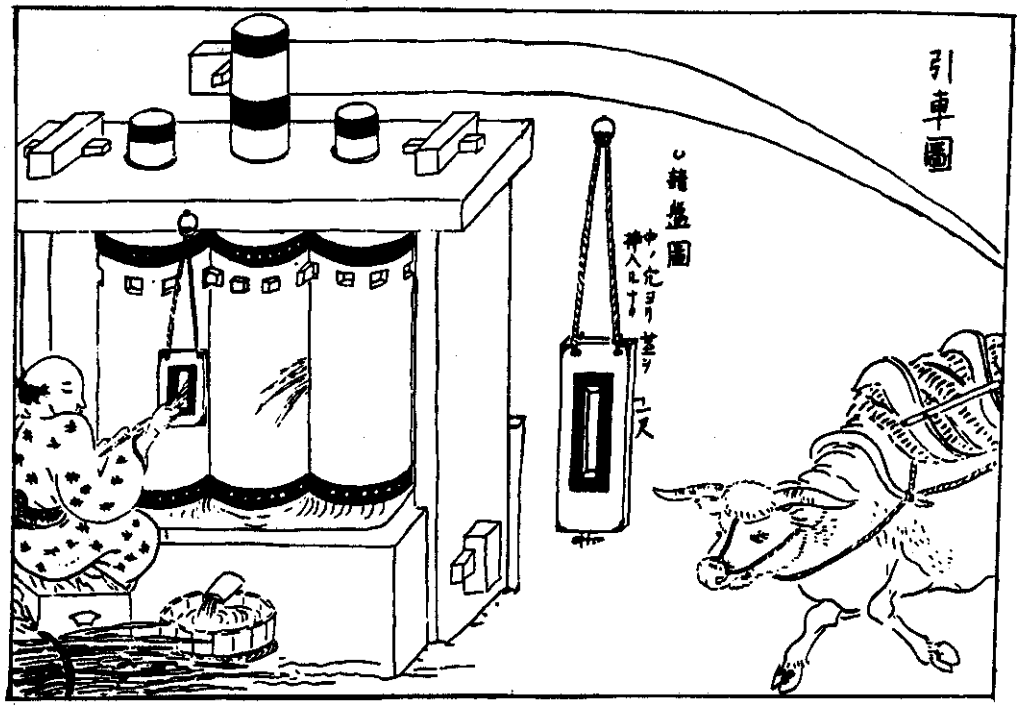


Fig. 114. The first known illustration of a three-roller vertical sugar mill in Japan, included in the *Kansha Zōsei Den* of +1760, pp. 6b–7a, by Tamura Genyū in the collection of the Kyōu Shooku, Osaka, Japan. From the late 1750s, the Japanese began experimenting with double- and triple-roller mills, using wooden, iron-plated wooden and stone rollers. The straight cog gearing and the harness display remarkable resemblance to the illustration of Hiraga Gennai in his *Butsurui Hinshitsu* of +1763. Tamura has taken extreme care in depicting how the pressure feeding device works by drawing it twice. The caption beside the feeder inset on the right side of the mill reads, 'Sugarcane stalks are inserted through the hole in the middle.'

adequate, ordered the Chinese to bring a wooden model of a mill on their next visit (*shih chhê yang shih tsai lai chih jih i mu thou tso chiu tai lai*[1]).[a] Since this mill came from China I assume that it only had two rollers.

The *Kansha Ki*[2] (An Account of Sugarcane) of +1764, an unpublished manuscript authored by Gotō Rishun[3] (+1696 to +1771) with a preface and appendix by Katsuragawa Kuninori[4], the physician to the Shōgun[5], gave the various types of crushing machinery known to the Japanese by the mid +18th century:[b]

Before pressing (*shiboriyō*[6]) cut the cane stalks into pieces measuring two to three *sun*[7] [6–9 cm], pound them in a mortar and then put them into a bag and press them. In accordance with information from China recently three rollers (*kuruma*[8]) have been constructed. [The rollers] have a diameter of about 1.5 *shaku*[9] [45.5 cm] and are roughly two *shaku* [60.6 cm] high. Three of these rollers are set next to each other in a line and

[a] Oba (*1*), pp. 322–3.
[b] *Kansha Ki*, no pagination.

[1] 石車樣式再來之日以木頭作就帶來　[2] 甘蔗記　[3] 後藤梨春
[4] 桂川國訓　[5] 將軍　[6] 絞りやう　[7] 寸　[8] 車
[9] 尺

five or six people turn the middle one [thus activating the side ones by pushing the whim]. At present [the rollers] are driven by one oxen. The sugarcane stalks cut beforehand are inserted between the right and left rollers [after an initial crushing]. The left and right rollers revolve by the turning of the middle one, crush the cane stalks and the juice all flows down to the bottom ...

This text indicated that the Japanese had obviously experimented during the +18th century with at least two crushing processes apart from the two-roller mill introduced directly from China. The first, the double extraction process of pounding in a mortar and a secondary extraction in a press mentioned here, patently derived from the *Hsing-Hua Fu Chih*[1] of +1503, the relevant passages of which Katsuragawa Kuninori handcopied in his appendix to the *Kansha Ki*. The second, was the three-roller mill. Though this source claimed construction of a three-roller mill 'in accordance with information from China', we must doubt its veracity for the vertically mounted three-roller mill has never been satisfactorily documented in China, nor was it mentioned in the transcripts of information collected by Japanese officials from the Chinese at Nagasaki in +1726. Application of human power to drive vertically mounted three-roller mills appears to have been peculiar to Japan in the East Asian cultural area. Kimura Yoshiyuki in his *Satō Seisaku Ki* illustrated three-roller mills driven by two and four men (see Fig. 94) with rollers all of the same size.

Three-roller mills seem to have become favoured around the time of the *Kansha Ki* of +1764.[a] As mentioned earlier, crushing in a triple-roller mill did have certain time and labour saving advantages. With the triple-roller mill, sugarcane, passed for the first time between one side roller and the centre roller, could be received and immediately crushed again by feeding it back between the centre and side roll (see Fig. 94). Even Hiraga Gennai, who displayed great veneration for the Chinese double-roller mill, admitted that the advantage of inserting sugarcane from both sides of the rollers, made the triple roller configuration more convenient than the double roller.[b] This must have been the decisive factor in making the triple-roller mill so popular in Japan, and the *Satō Seisaku Ki* +1797 did not carry an illustration, or even a reference to a vertically mounted two-roller mill.[c] By the 19th century the triple-roller mill had attained a predominant position in Japanese sugar milling.

Triple-roller mills could have emerged in Japan in two ways. First, they could

[a] Though not mentioned in the above passage, Gotō Rishun must have been aware of the double-roller mill as the sugar section of the *TKKW* was also reproduced in Katsuragawa's appendix.

[b] *Butsurui Hinshitsu*, Kan 6, p. 17b.

[c] The *Satō Seisaku Ki*, p. 405 recommended that poor people, desiring to make *kurozatō* without roller mills, crush sugarcane by cutting the stalks into small pieces and putting them into a press for extracting oil and persimmon tannin. This work also has an illustration of a hand-driven horizontally mounted two-roller mill which strikingly resembled a cotton gin, see Fig. 86. Ota ((1), p. 465) mentioned the use of a two-roller horizontal mill (presumably the same as the one illustrated in the *Satō Seisaku Ki*) for crushing only small quantities of sugarcane.

[1] 興化府志

have been transferred from the Ryūkyū or Amami Islands which were under the control of Satsuma *han*. Shōgun Yoshimune ordered Satsuma to send sugarcane clones from the Ryūkyū Islands in +1727, and appointed retainers to learn sugarcane cultivation and the art of sugar making in +1744.[a] Second, they could have been developed independently in Japan as the three-roller mill was merely an extension of the two-roller principle. But close contact between Japan and the Ryūkyū and Amami Islands after the Satsuma invasion of +1609 makes the chances of independent innovation in Japan very slim. I believe that the triple-roller sugarmill entered Japan from either the Amami or Ryūkyū islands somewhere between +1727 and +1744. Satsuma had no reason for blocking the transfer of technology at this time, as sugar production had not yet begun on the main Japanese islands.

Katsura Masaki has recently advanced an interesting theory on the transfer and diffusion of the roller mill in Japan based on an ethnographic study.[b] He distinguished two different types of roller mills, the Chinese and south-western Japanese types, according to roller diameter, turning direction of rollers and usage. The Chinese type entered Japan through Nagasaki, and was adopted in Owari[1], Sanuki[2], Awa[3], Iyo[4] and Higo[5]. Its characteristics included:

1 a roller diameter of between about 40 and 60 cm
2 the rollers turned in a clockwise direction
3 all places that adopted it manufactured white sugar.

The south-western Japanese type, which came in through the Ryūkyū and Amami Islands and reached Satsuma[6], Hyūga[7], Tosa[8], Edo[9], Musashino[10], Kishū[11] and Izumi[12], exhibited the following characteristics:

1 a roller diameter of roughly between 15 and 30 cm
2 the rollers turned in an anti-clockwise direction
3 all places that adopted it manufactured black sugar (*kurozatō*).

Katsura argued that since the south-western Japanese type had a thin roller diameter, it could not have derived from China for the *Thien Kung Khai Wu* roller measured 70.4 cm, and speculated that it could have come from South-East Asia. Indian rollers had thin diameters of about 20 cm, but we have no evidence of transfer. Since we have proof for the transfer of sugar technology from China to the Ryūkyū islands in +1623, I suggest that the changeover to a thin diameter may have taken place either in the Ryūkyū or in the Amami Islands.

[a] Higuchi (*2*), pp. 74–6.
[b] Katsura (*1*), pp. 188–96.

[1] 尾張 [2] 讃岐 [3] 阿波 [4] 伊予 [5] 肥後
[6] 薩摩 [7] 日向 [8] 土佐 [9] 江戸 [10] 武蔵
[11] 紀州 [12] 和泉

Sugar refining technology

Japanese sugar makers studied Chinese coning and claying techniques from the +1503 *Hsing-Hua Fu Chih*, the *Min Shu*[1] of +1631 and the *Thien Kung Khai Wu* of +1637, as well as interrogating Chinese visiting Nagasaki.[a] Since the *Satō Seisaku Kī* of +1797 described and illustrated claying, it is evident that the Japanese did experiment with these methods for a time.[b] However, by the close of the +18th century sugar makers in Sanuki on the island of Shikoku, had developed a different technique for removing the molasses film surrounding the sugar crystals, to make white sugar. It consisted of adding small quantities of water to massecuite, kneading and then pressing out syrup. This indigenously devised technique, which we refer to as the *sanbon* method, would by the early 19th century surpass claying as the main method of separating crystalline sugar from molasses in Japan.

The *sanbon* method took several years to mature in the Sanuki area, but exactly when did it begin? Oka Mitsuo[2] gave the following account on the basis of supposedly reliable sources. In 1807 Sakiyama Shūkei[3], in an attempt to avoid the difficult task of cutting the dry white sugar from draining cones, devised a method of draining molasses from the sugar crystals by hanging it in wooden baskets woven from sugarcane leaves.[c] In 1808, a man called Shinbee[4] reputedly improvised a new method of separating sugar crystals from molasses by kneading massecuite (*shiroshita*[5]) on a round wooden board (see Fig. 115). A good quality white sugar resulted after kneading and draining three or four times.[d] In 1819 Kume Eizaemon[6] adopted a beam press used by *sake*[7] (rice wine) makers, to remove molasses from massecuite kneaded on trays.[e] Katsura Masaki has discovered two manuscripts which indicated that the *sanbon* method predated the supposed invention by Sakiyama Shūkei; the *Satō Seihō Kikigaki*[9] (Notes Taken While Listening to [Talks] on the Methods of Sugar Manufacture) and the *Satō no Seihō Hikae*[9] (A Memorandum on the Method of Sugar Manufacture) which related the instructions given by a certain Kameya Shinkichi[10] from Sanuki[11] at Futamigaura[12] in Banshū[13] on the Honshū side of the Inland Sea in 1800. These are exceptionally important sources for the history of sugar technology in Japan, but here we will only touch upon the description of the *sanbon* method. According to these documents, sugar makers in Sanuki prac-

[a] The *Kansha Kī* recorded how a labourer at Nagasaki by the name of Yoshiemon learnt the art of making white sugar from Lu Ssu-Ming[14], a Chinese sojourning there, during the early Kyōhō[15] period (+1716 to +1735) and taught it in Nagato[16], Owari and Edo, see pp. 466–7 below.

[b] *Satō Seisaku Kī*, pp. 391 and 402.

[c] Oka (2), p. 295.

[d] *Ibid.*

[e] *Ibid.*

[1] 閩書 [2] 岡光夫 [3] 向山周慶 [4] 新兵衛 [5] 白下
[6] 久米栄左衛門 [7] 酒 [8] 砂糖製法聞書 [9] 砂糖の製法扣 [10] 龜屋新吉
[11] 讃岐 [12] 二見浦 [13] 播州 [14] 盧思明 [15] 享保
[16] 長門

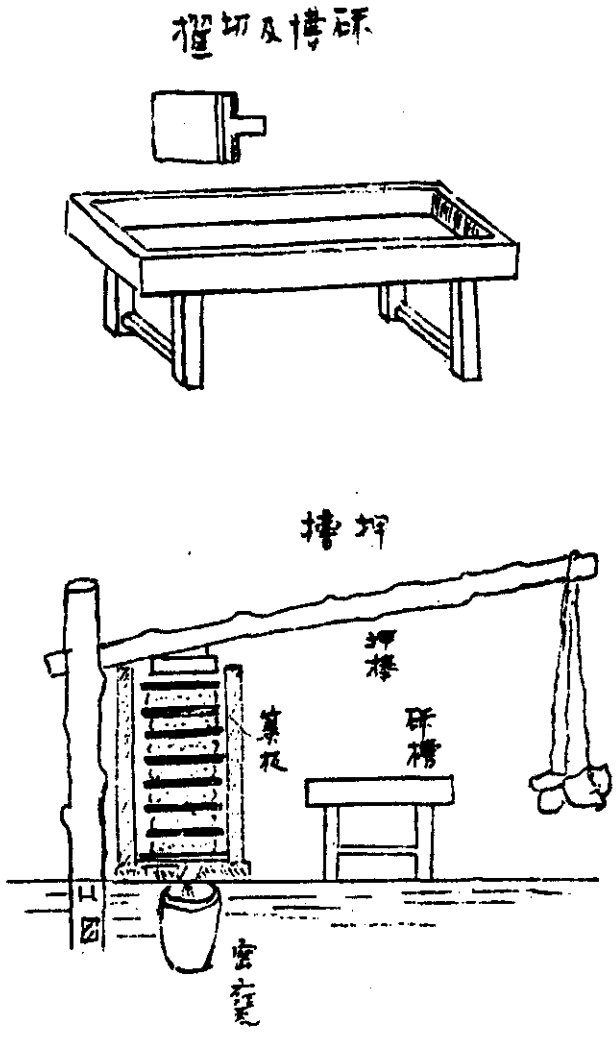


Fig. 115. A sketch of a kneading bench and beam press used by *sanbon* white-sugar makers in 20th-century Tokushima, Japan. Artisans repeatedly kneaded drained massecuite on the bench, called *togisō*[1], and pressed it in the beam press to remove more molasses, and make a fine-grained white sugar. The *oshibune* with sugar packed in bags with boards in between to equalise pressure are visible; after a drawing obtained from the Miki Bunko, Tokushima prefecture, Japan.

tised three techniques in the late +18th century. The first involved draining the massecuite in a cone, then placing it on a mat, sprinkling it with water containing dissolved *rokanseki*[2, a] powder and leaving it to dry in the sun. In the second technique the cone merely served as a utensil for cooling the boiled massecuite,

[a] It is not known what type of rock *rokanseki*[3] was. Hiraga Gennai in his *Butsurui Hinshitsu*, kan 2, p. 4b remarked that the best quality *rokanseki* came from China during the Ming, and that recent imports from China were only medium quality, but that from Yamashiro[4] was top quality.

[1] 研槽 [2] 芦眼石 [3] 爐甘石 [4] 山城

which was then drained in a basket woven from sugarcane leaves. Next the drained massecuite was kneaded on a mat a number of times. In the third technique sugar makers cooled the massecuite in a cone, drained it in a basket, and then pressed it in a *shimebune*[1] or beam press to remove the molasses before repeated kneading on a mat.[a] The last technique revealed innovation on the Chinese technique of claying, and was the obvious ancestor of the 19th-century method, and included the beam press, the common equipment of Sanuki *sanbon* manufacturers.

The significant part of the beam press arrangement was the *oshibune*[2], a large rectangular wooden box which contained bags of sugar piled one on top of the other; boards were inserted between each bag to equalise the pressure exerted by heavy weights hung on the end of the beam (see Fig. 115). The *oshibune* allowed a greater quantity of sugar to be squeezed with even pressure in a single pressing unit. The beam press was used for making soy sauce as well as rice wine, and the idea could have been borrowed from either process. Pressure from the weights on the beam press removed the molasses film leaving the sugar inside the cloth. Kneading with the addition of small amounts of water dissolved the molasses film on the outside of the crystals. The technique of alternative kneading and pressing dated from the late +18th century, and has remained essentially the same until today, though a few minor changes had occurred by the late 1870s when Ota conducted his study. A fine-grain soft white sugar known as *sanbon*, the whitest and best-quality sugar, was obtained by repeating the kneading and pressing process five times, and I have given this name to the technique. The chemical analysis by Ota revealed the effectiveness of the procedure, indicating an increase of 18.1 per cent sucrose, from *shiroshita* (massecuite) 80.5 per cent, to *sanbon* white 98.6 per cent.[b]

Why did sugar makers on Shikoku reject claying and devise their own draining technology? One possible explanation is that the imported Chinese methods did not suit Japanese climatic conditions. In south China with higher-purity juice, crystals grew large in the warm winters, so the sugar drained quite easily in a cone. The colder climate and lower purity juice of the high latitude Japanese sugar districts, however, yielded small crystals difficult to drain in a cone, without incurring a great deal of waste. Small crystals were prone to be washed away with the molasses by the water from the clay. By not relying on large quantities of water to wash away the molasses film, alternate pressing and kneading proved less wasteful than claying for refining fine grain sugar in a temperate climate. Nevertheless, as shown below, pressing and kneading still registered a 10 per cent greater loss than claying in warm climates. This suggests that it was probably a technique designed to refine sugar in a region climatically unsuited to pre-modern refining methods.

[a] Katsura (1), pp. 149–51.

[b] Ota (1), pp. 467–8.

[1] しめ舩

[2] 押舩

Authors often claim that this alternate pressing and kneading process was a unique Japanese innovation.[a] This, however, is far from being a completely accurate evaluation of the situation. North Indian manufacturers also removed the molasses film by pressing to make a similar sort of product called *dhulua*, a soft yellowish sugar. Artisans in India also placed sugar in wicker baskets to allow the molasses to drain away after an initial pressing.[b] The unique feature of the Japanese method lay in the repetition of pressing and kneading for four to five times, thus removing more molasses on each occasion. The Indians only pressed once and possessed no method for washing the molasses film from the sugar crystals.

Yet, the Japanese kneading and pressing operation was by no means more efficient than the claying process. Sources indicated losses in claying from about 17 per cent to 33 per cent in the West Indies during the +17th century, while 40 per cent loss in the Japanese pressing and kneading operation was the norm.[c] This probably arose due to the following two factors. First, with claying the sugar was only washed three times at a maximum, whereas with the kneading process it was washed four or more times. Second, and more importantly, the *sake* bag used to wrap the massecuite for pressing, adsorbed molasses, and sugar clung to it on each operation.[d] With a cone there was minimal adsorption or sticking of sugar to the surface.

The outstanding feature in the case of Japan was the process of borrowing and adaptation. Japanese sugar makers chose the sugar technology most suited to their situation from the best of what was available in East Asia during the first half of the +18th century, and modified it when necessary. After experimentation they finally favoured the three-roller mill of probable Ryūkyūan provenance rather than the double-roller mill imported directly from China, possibly because of the need to crush sugarcane within a short space of time before the onset of winter. The invention of a new draining technique adapted white sugar production to temperate climate conditions, and moulded the tastes of Japanese people for soft fine grain sugar. This consumer preference remains the same even in the present day with modern refined sugar. The initial stimulus for introducing and spreading sugar-making technology into Japan derived from the Bakufu, who played such as active role that one is tempted to draw parallels with the transfer to Japan of modern Western industrial technology during the late 19th century. Once diffused, strong impetus for modifying the technology came from feudal rulers, who found encouraging and protecting su-

[a] For example see Higuchi (*2*), pp. 146–7.

[b] Watt (1), vol. 6, pt 2, pp. 270–2 (for *dhulua*), and p. 281 (for draining).

[c] See Barrett (*2*), p. 163 for the West Indies; for Edo period Japan Higuchi (*2*), p. 150 recorded that only 60 *kin* (36 kilos) of white sugar were obtained from 100 *kin* (60 kilos) of *shiroshita* (massecuite).

[d] The far larger surface area of a bag with small crystals is also a pertinent factor. In Manila old sacks that held massecuite were sold to distillers, 'who steep them to dissolve the sugar remaining, and use the liquor for setting up their vats', see United States Consul (1), p. 74. In this case no real loss occurred, merely an alteration in product, but in Japan we have no evidence for similar practice as the Japanese did not distill alcohol from sugar.

gar production in their domains an important means of increasing *han* revenue.

Overall the Bakufu import substitution policy achieved considerable success. At the close of the +17th century Japan imported an annual average of approximately 3.5 to 5 million *kin* [2,100 to 3,000 tonnes] of sugar, but by the 19th century this fell to between 1.5 to 2.6 million *kin* [900 to 1,560 tonnes], indicating a gradual increase in the consumption of domestically made sugar.[a] But slowness in mastering, adapting and diffusing the imported technology characterised transfer under this policy. Eighty years lapsed from the time of initial transfer until production got underway in each *han*. The reason for the delay lay in the claustration policy which prevented Japanese artisans from learning directly from their Chinese counterparts. Though isolated cases of contact reportedly occurred, the weight of the system ensured that their influence remained minimal. Gotō Rishun, writing in +1764, related one of considerable interest;[b]

> Recently even in this country [sugar] has come to be made in Kyūshū[1], Sasshū[2] especially produces large quantities. But [they produce] only black sugar (*kurozatō*[3]), and do not know how to make white sugar (*shirozatō*[4]). In the early years of the Kyōho[5] period (+1716–+1735) a Chinese called Lu Ssu-Ming[6] arrived at the port of Nagasaki[7] in Hizen[8] on a merchant ship out of Nanking[9], and made white sugar from black sugar (*kurozatō wo seishi shirozatō to nashikeri*[10]) while staying at the Chinese residence (*shinkan*[11]).[c] This was dubbed the *kokuhakusei no hō*[12] [black white manufacturing technique], and was reputedly exceedingly secret even in China. At this time a native of Nagasaki, a labourer named Yoshiemon[13], always stoked the cauldron fire when Lu Ssu-Ming made white sugar from black (*kokuhakusei*[14]), and before long [he] saw how it was done, and was able to make it himself ...
>
> Using the technique of making white sugar from black, Yoshiemon succeeded in devising a way of manufacturing white sugar from the outset, and transmitted this technique to Yasuoka in Nagato no Kuni[15] for the first time. Since the result proved exceptionally excellent, next [he] travelled to Edo to transmit [the skill], but at that time no one knew how to grow sugarcane yet, so it was not possible to make white sugar. Thereupon [he] went to transmit [the technique] in Bishū[16] ...

Despite the assiduous efforts of Yoshiemon so early, immediate transmission proved impossible because sugarcane cultivation had not been mastered, and people remained uninterested; the true spread of sugar-making technology had to await the close of the +18th century. Leaving aside the question of authenticity,[d] this case demonstrated the extreme difficulty of transfer by a single Jap-

[a] Iwao (2), p. 24.
[b] *Kansha Ki*, no pagination.
[c] The *shinkan* refers to the Chinese residential quarters at Nagasaki.
[d] The authenticity of this account is suspect because it mentioned Yoshiemon learning the technique of making white sugar in the early years of the Kyōhō period (+1716 to +1736) which puts it before Shōgun Yoshimune's order to acquire sugar technology.

[1] 九州 [2] 薩州 [3] 黒砂糖 [4] 白砂糖 [5] 享保
[6] 盧思明 [7] 長崎 [8] 肥前 [9] 南京
[10] 黒砂糖を製し白砂糖となしけり [11] 清館 [12] 黒白製の法
[13] 慶右衛門 [14] 黒白製 [15] 長門國安岡 [16] 尾州

anese, even when blessed with the rare opportunity of studying at first hand from a chance visitor to Nagasaki, one of the only places where limited contact with foreigners remained possible. Prohibition of Chinese artisans entering the country meant a long time was required for the transfer and spread of the technology. This stood in contrast to the Ryūkyū islands where transfer and diffusion was achieved within a relatively short period of time because the State despatched artisans to China to study the art at first hand.

(5) Conclusions on the Transfer of Sugar-making Technology to East and South-east Asia

We have examined how Chinese sugar technology spread out into the countries of East and South-East Asia from the late +16th century to 1850, and seen the different ways in which they acquired it. Chinese immigrants and entrepreneurs brought technology to the group A countries, of the Philippines, Vietnam, Java and Siam; while the group B countries, of Ryūkyū, Amami and Japan obtained it by either sending technicians to China to learn it, or through books and information provided by occasional visitors. The nature of the source materials for each specific area forces us to generalise about the type of technology transferred, but, as the case studies demonstrated, adoption patterns varied with each country. Despite these limitations I believe that the evidence presented indicates, beyond doubt, a transfer of both agriculture and manufacture components of what I term the *Thien Kung Khai Wu* technological package, albeit with some changes in the B group. Though the technology itself dated from the late +16th century in China at least, it was not documented in detail until this work of +1637, hence the name. As a general rule, the technology taken overseas included all or most of the components described under (*d*) and (*e*), above, but sources do not permit us to trace the transfer of each one. Nevertheless, we do have solid factual knowledge about some, which allows us to assume the presence of the other components.

The *Thien Kung Khai Wu* technological package was comprehensive and in its essentials included:

(i) *Sugar-making clones*: Most countries in the A and B groups cultivated the Chinese sugar-making species, *Saccharum sinense* Roxb., for sugar making;[a] in the Philippines and the Ryūkyū–Amami–Japan area the transfer preceded the coming of *Thien Kung Khai Wu* sugar technology.[b] Although *S. sinense* was present in Java and Siam, the Chinese grew *S. officinarum* being more appropriate for the tropics.

[a] Rumphius (1), vol. 5, p. 188; de Loureiro (1), vol. 1, p. 51 for South-East Asia.

[b] Bodner & Gereau ((1), p. 350) claimed *Saccharum sinense* Roxb. was the oldest clone in the Philippines which suggests a presence prior to the +16th century; it was brought from Chiang-Nan to the Ryūkyū Islands sometime before +1429, from whence it was taken to Japan in the second half of the +17th or first half of the +18th century, as we have already seen.

(ii) *The plough*: Most countries employed the mould-board plough and hoe for land preparation, and that characteristically Chinese practice of ridging. I am also aware that Chinese implements, not listed in the *Thien Kung Khai Wu*, such as the traction spade were used in Java.[a]

(iii) *Extraction with two-roller vertical mill*: I have already given information on the two-roller mill for all countries in the A and B groups.

(iv) *Three-boiling pan unit*: Devised to conserve fuel it was employed in some locations, mainly in the large operations in Siam, some parts of Java and Hawaii.

(v) *Knowledge of crystallisation*: Sugar makers in all countries applied it to manufacture a range of sugars; massecuite, sugar candy, and twice-boiled sugars.

(vi) *Claying for white sugar*: All countries, except Japan, employed claying to make high-grade sugars.

The following factors characterised the transfer to A group countries:

(i) The whole technological package could be transferred precisely because Chinese immigrants did all the work from sugarcane cultivation to sugar manufacture themselves at the time of initial transfer. This was most prominent in plantations and sugar mills owned or contracted by the Chinese in Java, Sumatra and on the Malay peninsula. The continuous arrival of Chinese supported this typical pattern of transfer in South-East Asia by providing the technicians and skilled workers to keep business going, and the whole technological package, or parts of it, eventually spread to the indigenes with the passage of time and changes in domestic policy and society.

(ii) Since Chinese artisans undertook the work, sugar production began immediately without hindrance, and the requisite technology and skills were imparted directly to other Chinese and indigenes. This allowed transfer and diffusion to occur within a very short period of time.

(iii) The Chinese not only transferred their sugar-making technology, but in some areas acted as technologists and managers, consultants and operators. Chinese merchants still managed to supervise production after the transfer of the technological package to the local people, either completely or partially. Chinese merchants maintained quality control by advancing funds in cases like Vietnam, where the whole package had passed over into local hands, but exercised greater control over production in countries like Siam, where indigenes only grew the sugarcane and manufacture remained in Chinese hands. Since the sugar traded on the intra-Asian market between the +17th and first half of the +19th century was manufactured with Chinese technology, this type of direct and indirect technological guidance helped maintain relatively uniform levels of quality.

[a] See Vol. 6, pt 2, pp. 138ff for the plough in East and South-East Asia. For the traction spade see East India Company (1), p. 84.

(iv) Even though there were times, as in the Philippines and Siam when the State gave a certain amount of encouragement, it was Chinese immigrants, acting autonomously in response to shifts in intra-Asian trade, and not governments that effected the transfer. In other words, Chinese immigrants positively brought sugar technology to countries suited to production for personal gain. This is precisely the reason I have called it trade-induced transfer.

In contrast to A group countries, the Ryūkyū–Japan area poured forth a series of independent innovations not long after initial transfer. The following factors characterised transfer to B group countries:

(i) Ryūkyūans and Japanese could see the economic advantages of sugar production and knowing that the Chinese possessed the technology, strove to acquire the technology on their own initiative. The question they faced was how to get their hands on it.

(ii) The Ryūkyūans and Japanese came up with different solutions to the problem. Enlightened Ryūkyūan officials sent technicians to China to acquire the requisite skills, and the technology was transferred quickly without incident. The Japanese, who were prohibited from travelling overseas and having contact with foreigners, had to learn it themselves from books, by interrogating Chinese merchants and by experimentation.[a] This resulted in a long period of time, approximately eighty years, in effecting transfer, taking root and spread of sugar technology. Though the Bakufu started to encourage domestic production of sugar to redress its international balance of payments, the goal was doomed to elude realisation within a short period of time from the outset, because of the restrictions of the closed-door policy.

(iii) The claustration policy of the Bakufu inevitably resulted in Japanese artisans questioning and being forced to innovate on certain elements of *Thien Kung Khai Wu* technological package, as they assiduously tried to master it. Many improvements were made to the Chinese double-roller vertical mill. In the Ryūkyūs in +1671, Makiya Sanekiyo devised a three-roller vertical mill from the Chinese double-roller mill. In the Amamis in +1717, Tabata

[a] Innovation by literature needed a formidable amount of commitment often lacking in artisans, scholars and administrators. An extraordinary case of the failure of technological transfer by literature alone is given in Inoue (*1*). The 'latest' European methods of manufacturing white sugar were said to have been expounded in a book entitled, *Schule der Chemie* of 1864 by the German agricultural chemist, Julius Adolf Stöckhardt. In the last years of Tokugawa rule it was translated by Kawamoto Kōmin[1] (+1809 to +1871), of a family who had served as physicians to the Sanda[2] domain in Hyōgo[3] for generations. Kawamoto translated from the Dutch rendition of I. W. Gunning, *De Scheikunde van het Onbewertuigde en Bewerktuigde Rijk* of 1855. Satsuma *han* tried to get Kawamoto to transfer the new technology but he never visited Satsuma, and the method was never applied by him in their domain. I have not been able to locate either Stöckhardt or Gunning in any of the standard histories of sugar, and the 'latest' methods may have been trivial, but the incident demonstrated the strong commitments necessary to achieve success by literature transfer.

[1] 川本幸民 [2] 三田藩 [3] 兵庫

Sabuni positioning the rollers horizontally, harnessed it to a waterwheel, and in 1808 Kashiwa Yūto capped the rollers with iron. The Japanese, after comparing double- and triple-roller vertical mills adopted the latter from the late +18th century, and displayed a certain degree of originality in contriving complicated configurations for water and human power. The enthusiasm of Japanese artisans for improvement was visible in Fig. 95. Again the Japanese chose not to adopt coning and claying for white sugar, but developed their own hand kneading and pressing techniques. As stated earlier, these were not techniques unique to Japan as north Indians practised similar methods. In the long run, it would seem that the drive for domestic production aroused enthusiasm amongst artisans for technological improvement, and probably nurtured that strong interest in adapting foreign technology to local needs which manifested itself in the industrialisation of Japan.

We can conclude that this study confirms Cipollas' model of technological transfer which posits transmission by the migration of people. At the same time we also detect a phenomenon not mentioned for Europe, adaptive innovation induced by lack of migrants. In the Japanese-influenced area where free access to receiving instruction from foreign artisans was denied, innovation became noticeable; indigenous artisans adopted three-roller vertical mills, capped wooden rollers with iron, experimented with multi-roller mills, and developed a new system of kneading massecuite and pressing out molasses. These innovations laid the technical foundations of sugar production before the opening of the country to foreign trade in the mid-19th century.

(*g*) EPILOGUE AND OVERVIEW

I have already discussed the significance of each of the component sugar technologies in the conclusions given at the end of each sub-section. Here I will provide short concluding remarks about the contribution that the concept of agro-industries can make to the history of Chinese technology, briefly discussing the Chinese preference for not adopting modern central integrated sugar factories in the light of oecumenical technology. I will also take a look at the oecumenical status of the other selected agro-industries.

As demonstrated in this account of sugar, agro-industries shared a common technological tool kit, the contents of which changed to suit, or perhaps even encouraged, shifts in the Chinese economy and society. More detailed studies of additional agro-industries are needed to deepen our understanding, but at this stage we can safely point to one important usage of the concept, that is as a yardstick with which to judge historical change. Historians generally view the economy and technology of China as progressing ever upward, and are always eager to show how one particular period differed from another. In studying pre-

modern history lack of data often makes it difficult to pin-point concrete indications of qualitative change. For instance, how does one go about indicating the qualitative difference between the economy of the Sung and Ming dynasties both of which boasted large urban markets, a money economy, landlord–tenant systems and many other similar features. Scholars have drawn attention to the increase in the amount of money in circulation due to the import of foreign silver during the Ming, changes in the land-tenure system, differences in State policies, and other factors. The history of agro-industrial technology can also contribute to our understanding by offering a concrete measure with which to judge the qualitative shifts in society and economy over long periods of time.

The definitive feature of the change in sugar technology was the clear progression towards a system of production which embodied more reliable, faster methods of manufacture between the Sung and Ming. The Imperial bibliographers of the *Chhin Ting Ssu Khu Chhüan Shu Tsung Mu Thi Yao*[1] (Analytical Catalogue of the Books in the *Ssu Khu Chhüan Shu* Encyclopaedia, Compiled by Imperial Order) of the +18th century realised that improvements had taken place in sugar-making technology since Wang Cho[2] wrote his *Thang Shuang Phu*[3] in the mid +12th century;[a]

> [Wang] Cho said that the best sugar candy was purple in colour and the worst white, but in the present day white is prized and purple is held in low regard. Cho stated that sugar candy required a year and a half to crystallise (*chieh*[4]), and that its crystallisation depended on nature. Now it is exceptionally easy to make it, but the method [of manufacture] is not the same. This [is due to] the difference in modern and ancient ideas of suitability, and one cannot judge people of former times by what came afterwards.

The unreliable nature of Sung sugar-making technology limited it to a few specialist areas, whereas by the late Ming (+16th century) improvements in extraction, crystallisation and draining techniques made production more efficient. The advent of the double-roller mill increased crushing rates, and the adoption of reliable crystallisation and draining techniques facilitated its use by greater numbers of agriculturalists, and made manufacture of crystal sugar possible on a larger scale than ever before. As the Imperial bibliographers remarked, this qualitative change from dependence on nature to reliance on human skill, really did make the manufacture of sugar more reliable. In fact this new technology may well have even cut producers' costs, causing a drop in the market price of sugar, and consequently encouraging the large growth of a consumer market after the +16th century, but in the absence of solid price data this remains within the realms of mere speculation.

The emergence of a new sugarcane agriculture and sugar manufacturing technological tool kit after the +16th century made possible all of these economic changes, and its transfer overseas laid the foundation for the growth of

[a] *Chhin Ting Ssu Khu Chhüan Shu Tsung Mu Thi Yao*, p. 990.

[1] 欽定四庫全書總目提要 [2] 王灼 [3] 糖霜譜 [4] 結

sugar production in other East Asian and South-East Asian countries. The Chinese did not invent the new technology out of the blue, but rather re-arranged and reshuffled existing technologies to meet the demands of the newly expanding domestic Chinese and intra-Asian trade markets. Many components of the technological kit had a long history in China; Chinese agriculturalists had used the mould-board plough since the Han dynasty, precipitation technology and lime as a reagent had been used for indigo making since the +6th century at least, just to mention a few. The only really new addition to the kit was the vertical double-roller sugar mill which Chinese engineers had devised from an ungeared double-roller horizontal mill introduced from India. In the past the Chinese had displayed great ability to incorporate various new or foreign techniques, having adopted the art of crystallising sugar by beating from the Indians in the mid +7th century and coning from the Islamic world probably sometime in the +13th or +14th centuries. The new sugarcane agriculture and sugar technology kit owed its origin to accumulated knowledge rather than 'invention', and was adjusted to suit the small farmer mixed crop economy. This link between the system of land tenure and technology was never truly broken until the revolution of 1949; no amalgamation of landholdings took place to enable the adoption of a central mill system in the sugar districts, and the Chinese government did not initiate measures to change the infrastructure. This sets the Chinese experience apart from that of tropical America and European colonies in Asia, and I suggest that the lack of change in the size of landholdings along with the nature of the Chinese consumer market, probably helped extend the application of their technology into the mid-20th century.

In order to understand why the Chinese did not adopt central integrated sugar factories it is helpful to review the situation in the context of oecumenical technology. Comparative studies with Europe and the New World reveal three levels of oecumenical sugar technology. World sugar manufacturing areas reached the first level of oecumenical technology in the Sung. Manufacturers used edge-runners and secondary pressing from China through the Middle East to Mediterranean Spain, along with similar boiling techniques. This crushing equipment along with other technologies such as draining sugar in cones, were transferred to the New World in the +16th century. A second level of oecumenical technology appeared with the diffusion of new sugar technologies, such as vertical roller milling and claying of sugar in cones. These technologies diffused so quickly that it is difficult to detect their primary place of origin. The Canary Islands and Madeira were early centres of excellence, and Peru and Pernambuco in Brazil followed. In Asia, China was the main centre and innovator of oecumenical sugar technology, from which second level technologies spread to South-East Asia, Indonesia, Philippines, Okinawa and the Japanese islands. Paradoxically at the point when sugar production became truly oecumenical at level two, with Indian involvement at the commencement of the

19th century, the advent of more advanced level three technology broke the concord; high capital costs prevented it gaining general acceptance among Asian manufacturers.

The new level three technology grew out of the advent of steam for powering crushing engines and heating, plus a higher level of understanding of the processes through the researches of Dutrône la Couture[a] in the French colony of St. Domingue (modern Haiti) in the period +1784 to +1789. He was the first to realise that sugarcane juice processing consisted of the unit processes: clarification, evaporation, crystallisation and draining, and he rightly saw that these unit processes needed separating to be effective. If confounded in a Jamaica train or Chinese clover leaf, juice can be under clarified, or syrups badly managed at crystallisation point, due to pressures of volumes in a continuous operation without intermediate holding tanks. The system of Dutrône la Couture[b] did not require any major capital expenditure, only more intelligent management. Though the great slave revolt commencing on the night of 22 August +1791 destroyed the sugar industry of St. Domingue, the largest in the contemporary European known world, as well as the first fruits of Dutrône la Couture's researches. However, Dutrône la Couture, who had returned to France by +1789, and published his principles in the *Précis sur la canne et sur les moyens d'en extraire le sel essential* in the following year. This work had considerable impact on the French sugar colonies and the beet industry as well. In addition, Dutrône la Couture either wrote the article on sugarcane in the +1790 edition of the great *Encyclopédie* of Diderot and d'Alembert, or it was based on his *Précis*. The hygrometer and a table of temperature elevation for crystallisation were adopted in the beet industry for evaporation and crystallisation respectively. The *Précis* had a great impact in the English speaking world through George Richardson

[a] Jacques-François Dutrône la Couture (+1749 to 1814) from a rich bourgeoisie family, was educated as a physician and practised in Normandy. In +1784, he proceeded to St Domingue apparently in an official position to study sugar manufacture. At the time St. Domingue was the largest sugar producer in the world, and he developed his system in the factory on the Estate of a M. Deladebate. Dutrône la Couture returned to France in +1789 and published his *Précis sur la canne et sur les moyens d'en extraire le sel essential*, in +1790. He then wrote several pamphlets on the favourable economics of colonialism and the necessity for slavery. Dutrône la Couture applied to return to St. Dominigue in +1792 as Commissaire, but was rejected. He was one of the organisers of the abortive royalist uprising of 3 October +1795 crushed by a young officer, Napoleon Bonaparte, and spent several years in prison. He died in 1814 after publishing two books on economics and politics, which were described as obscure and incoherent, see d'Amat (1), fasc. 70, p. 943.

[b] In Dutrône la Couture's system clarification was conducted in separate vessels. The juice was limed, skimmed and filtered, and clarification was completely finished before passing to the evaporators. Evaporation continued until about 43% solids (24° Baumé) were obtained, as determined by a hygrometer. It was then stored in tanks for several hours for subsequent crystallisation, to allow any extraneous matter to settle out. Trusted slaves performed these operations continuously night and day. Crystallisation was only done on day-shift under the supervision of the operations manager and controlled by continually measuring the temperature. The elevation of temperature of boiling is proportional to the concentration of sucrose; Dutrône la Couture constructed a table by experimentally relating juice concentration to temperature. The massecuite was then stored in coolers. All the vessels and processes described to date were performed in an area known as the laboratory. From the laboratory cooler the massecuite was passed to large shaped cases for slow cooling and stirring to promote crystal growth. The sugar was then drained or clayed.

Porter's detailed summary in his *The Nature and Properties of the Sugarcane* of 1830. A series of inventions were applied subsequently to the unit processes to create a highly capital intensive system which included:[a]

1 crushing with horizontal roller mills powered by steam (from +1768, John Stewart in Jamaica,[b] common by +1820).
2 improved individual clarifiers (from 1775, Sainthill and Baker in Jamaica, common by the early 19th century).
3 vacuum pans for evaporation and boiling at lower temperatures with more precision and lower sugar losses. (Edward Charles Howard patented the invention in 1813 which was pioneered in sugar refineries, but it was 1832 before any found application in raw cane-sugar manufacture, and 1835 in the beet industry.)
4 multiple-effect evaporators for economical evaporation of water. Three vacuum pans were arranged in a row with progressive increase in vacuum. The vapour from one was used to evaporate the liquid in the next, resulting in great economy of steam. (Norbert Rillieux built the first multiple-effect evaporator in Louisiana in 1845.)
5 centrifugals for spinning syrup out of massecuites. This reduced a 30-day drainage period in cones to an operation of a few minutes that was far more effective. (Sugar centrifugals derive from an 1837 French patent of Penzoldt, to dry textiles. A French patent, Seyrig 1843, was successful and many machines were sold in the French colonies, though it was the 1850s before they went into operation elsewhere.)

Readers need exercise little imagination to realise that a factory combining the technologies outlined in this inventory lay beyond the means of Asian peasant farmers, and even European family plantation owners, using second level oecumenical technology which relied on massive amounts of slave, bonded or free labour. As Galloway (4) has demonstrated, sugar production had to be completely reorganised, or more specifically centralised, around new machine-operated factories called 'centrals'. Some of the first examples of these integrated factories have been captured in a magnificent series of coloured plates of Cuban mill interiors by Cantero in the 1850s.[c] Centralisation demanded a large amount of capital and a massive degree of social reorganisation which included:

1 the amalgamation of family run estates into larger size plantations by entrepreneurs or corporations employing elite managers and technologists who di-

[a] Summarised from Deerr (1) and Galloway (4).
[b] Deerr & Brooks (2). Stewart's adaption of a steam engine to crush cane was the first application of steam power to operate machinery in a manufacturing process.
[c] Cantero (1). The exterior illustrations showed steam locomotives and extensive rail systems for delivering the sugarcane harvest to the mills. These illustrations of the railways and canefields are very striking and are of high artistic merit.

rected paid labour in the growing and the processing of the sugarcane crop (for example Cuba, Hawaii).

2 large corporations building efficient central mills which they operated by buying cane from peasants or small farmers (for example Fiji, Australia).

3 large central factories owned by small farmers who supplied co-operatively run factories. These only eventuated with government assistance (for example some parts of Queensland, Australia).

These scenarios were only indicative, as in practice most reorganisation involved exceptionally complex changes and only took place in stages. At two recent excellent conferences on world sugar history, participants apparently thought the technological component of the 19th-century *perestroika* to be the adoption 'wholly or partly, of the new mechanized European beet-sugar technology.'[a] Reference to the summaries of the five relevant inventions above shows that most were associated with sugarcane initially and the intellectual framework of unit processes and basic instrumentation codified by Dutrône la Couture in St. Domingue before 1800. The beet manufacturers of the later 19th century achieved a commercial advantage over sugarcane processors by applying the available technology faster and more widely than sugarcane growers.

The most common first step was to install boilers for powering crushing engines and boiling syrup by steam. These innovations dramatically increased factory rates, but exercised little influence on quality. The new technology, such as vacuum pans and centrifugals, which came later (often well into the 20th century) increased sugar quality; it enabled manufacturers to change from making muscovado sugar of about 80 per cent purity in East and West[b] to production of centrifugal sugar of over 98 per cent purity.[c]

Consumers in some parts of the world, such as India and Latin America, remain satisfied with sugars made with level two technology, as they prefer the taste of the impurities, and modern dieticians have confirmed the advantages of minimally processed sugar. A number of agencies and governments have promoted technically efficient level two technology with equipment such as small steel roller mills and hand-driven centrifugals. In fact a movement called Indigenous Technological Change (ITC) has generated considerable research aimed at providing peasants and small peasant co-operatives with improved level two technology that they can afford. These developments have also led to much discussion on scale of operations in an 'appropriate technology' debate.[d]

Next let us outline the oecumenical status of the agro-industrial crops we encountered at the beginning of this study.

[a] Schnakenbourg (2), p. 87. See also Albert & Graves (1), p. 1 and Albert & Graves (2), p. 2.
[b] Yamane (1). [c] Patterson (1).
[d] See Kaplinsky (1) for an extensive study of ITC and appropriate technology, along with a large bibliography. Delasanta & Morgan (1) made a perceptive study of ITC and appropriate technology for Pakistan sugar industry. Degregori ((1), p. 214) gave a general bibliography on small-scale technologies in China.

Oil and oil seed crops

What I have called level one oecumenical sugar technology, employing the edge-runner and secondary pressing, derived from oil seed processing. Its transfer to Persia and Mediterranean Europe resulted in the appearance of an oecumenical seed oil technology by the Sung dynasty. The changeover to a level two technology using roller milling for extracting oil, did not become possible until the advent of steel roller mills that could be adjusted accurately to process small seeds. Thomas Platt set up a steam-powered soybean mill at Newchwang in 1868 with money borrowed from Jardine, Matheson & Co. Platt defaulted, but Jardine decided to proceed; the mill became operational in the spring of 1869 and worked well technically. The oil-yield rate was lower than the traditional large edge-runner and secondary press, but the managers expected that the lower yield would be offset by higher productivity in labour and capital. To achieve productivity it proved necessary to introduce more authoritative systems of management than used by local millers. This resulted in strikes and 'go slows' which when combined with failure to purchase soybeans direct from growers due to guild intervention, caused a closure after the third season. A rapid expansion of foreign and Chinese-owned steam-driven mills occurred after the treaty of Shimonoseki in 1895 which clarified the legal status of foreign investments in the treaty ports.[a] The soybean industry turned into a major export industry in the 20th century, by the mid-1910s there were twenty large, steam-powered, Chinese-owned mills in China.[b] The traditional edge-runner and secondary pressing survived into the 20th century alongside these new factories, presumably because they gave better yields (but lower quality) than steam-driven technology.[c]

Paper

Paper was of great interest because it originated in a single area, China, and spread from this centre as a reasonably mature technology. It dispersed to Vietnam and Japan in the +3rd and +6th centuries respectively, mainly through the agency of Buddhists, and arrived in Persia in the +8th century and in India possibly by the +11th century. India served as a secondary centre of dispersal to the Indianised states of South Asia, and from Persia paper manufacture spread to the Mediterranean to north Africa and Spain by the +10th century with the Muslim expansion.[d] An oecumenical level was reached by the +12th century with the unit processes of pulping, cooking, pounding, additives for texture, felting on screen, washing and drying. The situation remained static in

[a] This section on steam-powered oil milling relied on Brown, S.R. (1) and Brown, S. R. (2), pp. 191–2.

[b] Couling (1), p. 46.

[c] Jardine's manager at Newchwang noted that the oil was of better quality and the resulting soybean meal richer, than with the traditional edge-runner/secondary press; he thought he would have a quality advantage, see Brown S. R. (2), p. 191. I noted on p. 338 a similar phenomenon of higher purity with sugarcane roller milling versus edge-running. Edge-running/secondary pressing extracted more product and more impurities.

[d] Datings from Vol. 5, pt 1.

principal until the advent of heavy pulping machinery and the paper-making machine of Louis Robert in France in +1799.[a] Three mills employing this type of machinery were constructed in China by the 1910s, the most successful being under Japanese management.[b]

Indigo

Plants furnishing blue dyes grew world-wide and essentially the same basic method of extraction developed *in situ*, probably because the actions involved were not critical, and a result of sorts could be easily obtained. The first methods probably centred on the dry 'fermentation' of intact leaves such as survives as a cottage industry in Japan. By the +17th century the basic technique of extraction in warm water, 'fermenting', beating to oxidise, settling, boiling, and drying, had become essentially oecumenical as noted in Alden (1). The distinct differences in Chinese technology arose from emphasis, not from principle, demonstrating that attention to detail was not critical for getting results. Use of mechanical aids appeared in the French Caribbean,[c] but they never became widespread. In the later stages of the Industrial Revolution during the late 19th century, indigo making did not progress into a high level, post-Industrial-Revolution industry, because of von Bayer's chemical synthesis of indigo in the late 19th century. In China indigo production declined in the early part of the 20th century as synthetic dyes gained ground, but experienced a temporary revival in World War I, when imported synthetics became in short supply.[d]

Lacquer

The lacquering process could never be truly oecumenical because the trees of family Anacardiaceae that yield the feedstock latex, were restricted to East and South-East Asia. However, the distribution of Chinese lacquer products westwards, resulted in the appearance of substitute products; lac in the Middle East and varnish in Europe. These substitute feedstock gave very similar results to the original lacquer latex, but by evaporation of a solvent rather than by the hardening of the latex. The lacquer concept thus achieved only dubious oecumenical status.

Tea

Tea manufacture originated in China, and like sugar displayed an array of products and quantum jumps in levels of technology. The tea plant probably spread out from a centre near the source of the Irrawaddy to south-east China, Indo-China and Assam.[e] Level one technology, which probably arose in the Thang, involved lightly withering, steaming and pressing tea leaves into

[a] Clough (1), p. 300. [b] Couling (1), p. 423.
[c] Beauvais-Raseau (1) described and illustrated mechanical aids in the French Caribbean such as edge-runners for squeezing the mash after extraction and animal-driven machinery for beating to oxidise the extract.
[d] Couling (1), p. 151. [e] Eden (1), p. 1.

brick moulds. These bricks continued to be traded in the 20th century. Level two technology, which commenced in the Ming, included the preparation of black tea with four more or less distinct unit processes: withering, rolling (maceration), oxidation and firing. This yielded a stable product for export to Europe in increasing quantities after the +18th century. This technology remained the province of China and surrounding countries until the 19th century, when European entrepreneurs stimulated by colonial government agencies, formed limited liability companies to produce tea under a plantation system in India from the 1830s, Ceylon in the 1870s, Java from 1824,[a] Durban from 1877, Malawi from 1891 and tropical and sub-tropical areas followed in the 20th century. These plantations applied level three technology which basically involved the mechanisation of the four unit processes detailed above along with new labour relations. Tea production was distinct in that it diffused world-wide late (19th century) as a relatively mature technology, all the basic unit processes having been developed in the area of origin, China. India proved to be a secondary centre for technology development and dispersal through colonial contacts. The Indian government introduced Chinese tea makers and artisans to Assam in 1837 and the resulting tea sold so readily on the world market, that the industry was financed by the Assam Company.[b] India and fledgling industries in other countries were also helped considerably with the careful documentation of the Chinese experience by Ball, Fortune and others. Even with this knowledge it usually took several years to establish production. After the destruction of the Canton monopoly in 1842, some foreign firms moved to Foochow where they pioneered up-country tea purchasing, and by the 1860s improved methods of firing and packing. Chinese competitors rapidly acquired these techniques, being an interesting case of technology transfer feed-back.[c] After 1870 in China, foreign entrepreneurs endeavoured to acquire land outside the treaty ports to establish the plantation systems that had been so successful in India and Ceylon. However, only the Russians found a niche in the preparation of brick tea for export to Russia. This brick tea was prepared in Hankow and Foochow from tea dust and low quality leaves bought from Chinese firms by simple steam-powered presses which delivered firm uniform bricks easily packed for export. Some small Chinese firms participated in the business.[d] Viewed in the long term the Chinese peasant-based tea industry could not maintain its export status in competition with the overseas plantation style enterprises, and its share of the world market subsequently fell from 90 per cent to 29 per cent in 1905. By 1920 the tea exports had ceased to be significant and only amounted to 1.6 per cent of total Chinese exports.[e]

[a] Six journeys were made between 1827 and 1833 by a government officer to collect seed and workmen from China, see Eden (1), p. 2. Jacobson, inspector of tea cultivation in Java, wrote a treatise on tea cultivation and manufacture, Balfour (1), vol. 3, p. 829.

[b] Balfour (1), vol. 3, p. 834.

[c] Brown, S. R. (2), p. 188.

[d] *Ibid.*

[e] Ch'en, Jerome (1), p. 337.

It is quite apparent from this short overview that technology spread rapidly and attained an oecumenical level if it was successful. The major agent was movement of skilled people; outstanding examples were Buddhist monks in the pre-Thang period, the Muslim expansion in the Thang and Sung and European colonial governments (and entrepreneurs) after the +17th century. The Jesuits also served as a unifying technological factor after the +16th century. Apart from these generalisations, there were also numerous examples of individual initiatives such as the Buddhist sugar technological mission from India to China in the Thang and the Indian government importation of experts in tea growing and processing, combined with study tours in China, in the 19th century. It is a common cliché that Chinese technology was ascendant until the +17th and +18th centuries after which European technology became dominant. The above case histories confirm the concept.

Agro-industries displayed large differences in the amount of development possible. Sugar and tea went through several major levels of development, while other industries progressed with less spectacular adjustments. Ladislao Reti has shown that sugarcane and oil processing were some of the first industries to which Renaissance engineers applied the concept of an integrated factory (Reti (12)). It is also apparent that, amongst other forces that fostered the Industrial Revolution, the formative centuries of 'research' and 'tinkering', were necessary to truly understand the basic processes to which the machines and concepts of the Industrial Revolution could be applied. The recognition of key processes and development of appropriate technologies for their improvement made possible the 19th-century technical changes in the West and the world-wide small-scale appropriate technology of the 1970s and 1980s.

BIBLIOGRAPHIES

A CHINESE AND JAPANESE BOOKS BEFORE +1800, AND ALL GAZETTEERS

B CHINESE AND JAPANESE BOOKS AND JOURNAL ARTICLES SINCE +1800, EXCLUDING GAZETTEERS

C BOOKS AND JOURNAL ARTICLES IN WESTERN LANGUAGES

When obsolete or unusual romanisations of Chinese words occur in entries in Bibliography C, they are followed, wherever possible, by the romanisations adopted as standard in the present work. If inserted in the title, these are enclosed in square brackets; if they follow it, in round brackets. When Chinese words or phrases occur romanised according to the Wade-Giles system or related systems, they are assimilated to the system here adopted (cf. Vol. 1, p. 26) without indication of any change. Additional notes are added in round brackets. The reference numbers do not necessarily begin with (1), nor are they necessarily consecutive, because only those references required for this volume of the series are given.

Korean and Vietnamese books and papers are included in Bibliographies A and B. As explained in Vol. 1, pp. 21ff., reference numbers in italics imply that the work is in one or other of the East Asian languages.

CHINESE AND JAPANESE JOURNAL ABBREVIATIONS

CCNYKC	*Chê-Chiang Nung Yeh Kho Chi* (*Chê-Chiang Agricultural Science*)
CCYC	*Ching Chi Yen Chiu* (*Economics Research Journal*)
CHHP	*Chhing-Hua Hsüeh Pao* (*Ts'ing-Hua University Journal*)
CKNS	*Chung-Kuo Nung Shih* (*Chinese Agricultural History*)
CKSHCCS	*Chung-Kuo Shê Hui Ching Chi Shih Yen Chiu* (*Journal of Chinese Social and Economic History*)
CTFH	*Chih Thang Fa Hsiao*
DMN	*Dorumen* (*Dolmen*)
DNNH	*Dai Nippon Nōkai Hōkoku*
FCNHYHP	*Fu-Chien Nung Hsüeh Yüan Hsüeh Pao* (*Fu-Chien Agricultural College Journal*)
FCNYKC	*Fu-Chien Nung Yeh Kho Chi* (Fu-Chien Agricultural Science and Technology)
HKTL	*Hsiang-Kang Chung Wên Ta Hsüeh Yen Chiu Yüan Ti Li Yen Chiu Chung Hsin Yen Chiu Pao Kao* (*Research Report, Geographical Research Centre, Graduate School, The Chinese University of Hong Kong*)
ISTC	*I Shih Tsa Chih* (*Chinese Journal of the History of Medicine*)
KBKK	*Kobun Kazai No Kagaku*
KCHHP	*Khun-Chhung Hsüeh Pao* (*Acta Entomologica Sinica*)
KDTGKK	*Kansai Daigaku Tōzai Gakujutsu Kenkyūjo Kiyō* (Bulletin of the Institute of Oriental and Occidental Studies, Kansai University)
KG	*Kikan Ginka*
KGCS	*Kōgi Chōsa Shiryō* (*Research Materials for Promoting Technology*)
KKGEI	*Kagaku Kōgei*
KKR	*Kagoshima Keidai Ronshū*
KNK	*Kōnōkai Kaihō*
KTNYKH	*Kuang-Tung Nung Yeh Kho Hsüeh* (Kuang-Tung Agricultural Science)
LSYC	*Li Shih Yen Chiu* (Peking) (*Journal of Historical Research*)
MUS	*Museum* (Tokyo National Museum)
NB	*Nihon No Bijutsu*
ND	*Nanpō Dozoku* (*Nanpō Dozoku: the Ethnographical Journal of South-Eastern Asia and Oceania*)
NGK	*Nihon Gakushi'in Kiyō* (*Transactions of the Japan Academy*)
NNKK	*Nippon Nōgei Kagaku Kaishi*
NPBK	*Nanpō Bunka* (*Nampo-Bunka: Tenri Bulletin of South Asian Studies*)
NSKGS	*Nippon Shokuhin Kōgyō Gakkaishi*
OSHK	*Okinawa Shiryō Henshūjo Kiyō*
OSOBKK	*Okayama Shiritsu Oriento Bijutsukan Kenkyū Kiyō* (*Bulletin of the Okayama Municipal Museum of Near Eastern Art*)
PTG	*Ping Tu Hsüeh Pao* (*Chinese Journal of Virology*)
QBCB/C	*Quarterly Bulletin of Chinese Bibliography* (Chinese edition) (*Thu Shu Chi Khan*)
RK	*Rekishigaku Kenkyū* (*Journal of Historical Studies*)
SCYP	*Ssu-Chhuan Yüeh Pao* (*Ssu-Chhuan Monthly*)
SGZ	*Shigaku Zasshi* (*Historical Journal*) (Tokyo)
SJDSR	*Shūjitsu Joshi Daigaku Shigaku Ronshū* (*The Historical Review of Shūjitsu Women's University*) (Okayama)
SKS	*Shakai Keizai Shigaku* (*Social and Economic History*)
SZKKS	*Shikizai Kyōkaishi*
TAKK	*Tōa Keizai Kenkyū* (*Studies in East Asian Economics*)
TJKHSYC	*Tzu Jan Kho Hsüeh Shih Yen Chiu* (*Studies in the History of Natural Sciences*)
TJTP	*Thu Jang Thung Pao* (*Journal of Soil Science*)
TK	*Tōyōshi Kenkyū* (*Journal of Oriental History*)
TTTYCTFT	*Thien-Tshai Thang Yeh Chih Thang Fên Tshê* (*Handbook of Sugar-beet Manufacturing*)
TWFLHP	*Tung Wu Fên Lei Hsüeh Pao* (*Acta Zootaxonomica Sinica*)
TYG	*Tōyō Gakuhō* (*Journal of the Research Department of the Tōyō Bunko*)

WHCKY	*Wu-Hsi Chhing Kung Yeh Hsüeh Yuan Hsüeh Pao* (*Journal of the Wuxi Institute of Light Industry*)
WS	*Wên Shih* (*History of Literature*) (Peking)
WWTK	*Wên Wu* (formerly *Wên Wu Tshan Khao Tzu Liao, Reference Materials for History and Archaeology*)

TSHUNG SHU ABBREVIATIONS

CFTS	*Chi Fu Tshung Shu* by Wang Hao (*1*)
CPTCTSS	*Chih Pu Tsu Chai Tshung Shu*
CTMS	*Chin Tai Mi Shu*
HCTY	*Hsüeh Chin Thao Yüan*
LTTSSEC	*Liên-Thing Tsang Shu Shih-Êrh Chung*
SF	*Shuo Fu*
SKCS	*Ssu Khu Chhuan Shu Chên Pên Êrh Chi* of Wang Yün-Wu (*1*)
SL	*Shuo Ling*
SPPY	*Ssu Pu Pei Yao* (see Anon. (*556*))
SPTK	*Ssu Pu Tshung Khan* edited by Chang Yüan-Chi *et al.* (*1*)
SSIW	*Sung Shih I Wên Chih, Pu, Fu Phien* (Toktaga (Tho-Tho) *et al.*; Huang Yü-Chi *et al.* & Hsü Sung *et al.* (*1*))
TSCC	*Tshung Shu Chi Chheng* (See Anon. (*557*))
TSCCIWHC	*Thang Shu Ching Chi I Wên Ho Chih* (Liu Hsiu *et al.* & Ouyang Hsiu *et al.* (*1*))
TT	*Tao Tsang*
TW	Takakusu, J. & Watanabe, K., (1) *Tables du Taishō Issaikyō (Nouvelle édition [Japonaise] du Canon Boudhique Chinoise)*, Index-catalogue of the Tripitaka

WESTERN JOURNAL ABBREVIATIONS

AAAG	*Annals of the Association of American Geographers*
AAG	*Afdeling Agrariche Geschiedenis*
AAGR	*Annals of Agriculture*
AESC	*Annales Économies, Sociétiés, Civilisations*
AFB	*Africana Bulletin*
AGHST	*Agricultural History*
AGINT	*Agriculture International*
AHR	*American Historical Review*
AIEO/A	*Annales de l'Institut d'Études Orientales* (*Algiers*)
AIO	*Archaeology in Oceania*
AJI	*Agriculture Journal of India*
AJPH	*American Journal of Pharmacy*
ALSI	*Agriculture and Live Stock in India*
ANS	*Annals of Science*
ANTJ	Antiquaries Journal
ANYAS	*Annals of the New York Acadamy of Sciences*
AOAB	*Annals of Applied Biology*
ARLC/DO	*Annual Reports of the Librarian of Congress (Division of Orientalia)*
ASII	*Agricultural Situation in India*
ASP	*Asian Perspectives*
ASPR	*Asian Profile*
AVSNI	*Archief voor Suikerindustrie Nederlandsch Indië*
BCAS	*Bulletin of Concerned Asian Scholars*
BDCG	*Berichte der deutschen chemischen Gesellschaft*
BEFEO	*Bulletin de l'École Française de l'Extrême Orient* (*Hanoi*)
BIOMEM	*Biological Memoires*
BIONI	*Biocontrol News and Information*
BJHOS	*British Journal for the History of Science*
BLSOAS	*Bulletin of the London School of Oriental and African Studies*
BOG	*Botanical Gazette*
BRA	*Brasil Açucareiro*
BSCE	*Bulletin of the Sugarcane Expert* (Türkiya Fabrikalari A. S. [Turkish Sugar Factories, Istanbul])
BSCF	*Bulletin de la Société Chimique de France*
BSESAPNO	*Bulletin of the Sugar Experiment Station, Audubon Park, New Orleans*
BSN	*Behavior Science Notes*
CA	*Chemical Abstracts*
CBOT	*Chronica Botanica*
CENSSJ	*Central States Speech Journal*
CR	*China Review* (Hong Kong & Shanghai)
CRR	*Chinese Recorder*
CSSH	*Comparative Studies in Society and History*
CURRA	*Current Anthropology*
CYTOL	*Cytologia*
DWAW/PH	*Denkschriften d. Akad. d. Wissenschaften, Wien* (Phil.-hist. klasse)
ECB	*Economic Botany*

END	*Endeavour*
ENG	*Engineering*
EPW	*Economic and Political Weekly*
ETHH	*Ethnohistory*
ETHN	*Ethnology*
EUP	*Euphytica*
FTAUS	*Food Technology in Australia*
GEN	*Genetica*
GR	*Geographical Review*
HAHR	*Hispanic American Historical Review*
HJAS	*Harvard Journal of Asiatic Studies*
HJH	*Hawaiian Journal of History*
HP	*Hespéris*
HPR	*Hawaiian Planters' Record*
HS	*Historia Scientiarum*
HT	*History of Technology*
HUNTLQ	*Huntington Library Quarterly*
IJSRD	*Indian Journal of Sugarcane Research and Development*
INDS	*Indian Sugar*
INSJ	*International Sugar Journal*
ISIS	*ISIS*
ISSCT/PROC	*Proceedings of International Society of Sugar Cane Technologists*
ISSCT/SBN	*International Society of Sugar Cane Technologists, Sugarcane Breeders' Newsletter*
JA	*Journal Asiatique*
JAOS	*Journal of the American Oriental Society*
JBMHS	*Journal of the Barbados Museum and Historical Society*
JBORS	*Journal of the Bihar and Orissa Research Society*
JCE	*Journal of Chemical Education*
JCS	*Journal of the Chemical Society*
JDAPR	*Journal of the Department of Agriculture of Puerto Rico*
JEH	*Journal of Economic History*
JESHO	*Journal of the Economic and Social History of the Orient*
JHE	*Journal of Human Evolution*
JIBS	*Journal of the Indian Botanical Society*
JMHS	*Journal of the Malaysian Historical Society*
JOSHK	*Journal of Oriental Studies, Hong Kong University*
JPAH	*Journal of Pacific History*
JPOLS	*Journal of Polymer Science*
JRAS/B	*Journal of the Royal Asiatic Society of Bengal*
JRAS/M	*Journal of the Malayan Branch of the Royal Asiatic Society*
JRAS/NCB	*Journal of the North China Branch of the Royal Asiatic Society*
JRAS/SB	*Journal of the Royal Asiatic Society (Straits Branch)*
JSDO	*Journal de la Société des Océanistes*
JSOCA	*Journal of Society Arts*
JSS	*Journal of the Siam Society*
JTAA	*Journal of the Arnold Arboretum*
JTAS	*Journal of the Asiatic Society*
JWP	*Journal of World Prehistory*
KDVS/AKM	*Kgl. Danske Videnskabernes Selskab (Archaeol. Kunsthist Medd.)*
LARR	*Latin American Research Review*
LPSM	*The Louisiana Planter and Sugar Manufacturer*
MAI/NEM	*Mémoires de l'Académie des Inscriptions et Belles Lettres*, Paris (Notices et Extraits des Mss)
MAKC	*Makromoleculare Chemie*
MAST	*Modern Asian Studies*
MDAIBS	*Memoirs Department Agriculture India, Botanical Series*
MODC	*Modern China*
MRDTB	*Memoirs of the Research Dept. of Tōyō Bunko* (Tokyo)
MUFAB	*Mie University Faculty Agriculture Bulletin*
N	*Nature*
NC	*Numismatic Chronicle (and Journal Royal Numismatic Society)*
NCORO	*Nueua Coronica*
NEJM	*The New England Journal of Medicine*
NSN	*New Statesman and Nation* (London)
OLA	*Outlook on Agriculture*
OM	*Options Méditerranéennes*
ORA	*Oriental Art*
PEPE	*Pesquisa e Planejamento Econômico*
PJ	*Pharmaceutical Journal (and Trans. Pharmaceut. Soc.)*
PJSIR	*Pakistan Journal Sci. Ind. Res.*
PMED	*Planta Medico*
PMG	*Philosophical Magazine*
PNHB	*Peking Natural History Bulletin*
PNS	*Proceedings of the Nutritional Society*
POSMA	*Post-Medieval Archaeology*
PP	*Past and Present*
PPP	*Palaeography, Palaeoclimatology, Palaeoecology*
PTRSB	*Philosophical Transactions of the Royal Society* (Series B)
PV	*Pacific Viewpoint* (New Zealand)
RFHO	*Revue Français d'Histoire d'Outre-Mer*
RHC	*Revue d'Histoire des Colonies*
RICA	*Revista Instituto Colombiano Agropecuarte*
RTBN	*Recueil des Travaux Botaniques Néerlandais*
SC	*Science*
SES	*Senri Ethnological Studies*
SHMI	*Sheet Metal Industries*

SIC	*Studies in Conservation*
SITIP	*Proceedings of the Sugar Industry Technology Inc.*
SJ	*Sugar Journal*
SKS	*Shakai Keizai Shigaku* (Social and Economic History)
SM	*Scientific Monthly*
SPMSE	*Sitzungsberichte d. Physikalisch-Medizinischen Gesellschaft Erlangen*
SUGC	*Sugar Cane*
SWAW/PH	*Sitzungsberichte d. k. Akad. d. Wissenschaften, Wien* (Phil-hist. Kl.)
SYA	*Sugar y Azucar*
SZVDZ	*Sonderabdruck aus der Zeitschrift des Vereins der deutschen Zucker-Industrie*
TAG	*Theoretical and Applied Genetics*
TAM	*The Americas*
TAO	Wieger, L. (6), *Taoïsme*, vol. 1, Bibliographie Générale (catalogue of the works contained in the Taoist Patrology, *Tao Tsang*)
TAPS	*Transactions of the American Philosophical Society*
TAS/J	*Transactions of the Asiatic Society of Japan*
TBANZ	*The British Australian and New Zealander*
TCULT	*Technology and Culture*
THJH	*The Hawaiian Journal of History*
TIIC	*Transactions of the Indian Institute of Culture* (Basavangudi, Bangalore)
TNS	*Transactions of the Newcomen Society*
TNYAS	*Transactions of the New York Academy of Sciences*
TOOLT	*Tools and Tillage*
TP	*T'oung Pao*
TR	*Technology Review*
TRAHS	*Transactions of the Royal Hawaiian Agricultural Society*
TSC	*The Sugar Cane*
TSESR	*Taiwan Sugar Experiment Station Report*
UCLAHJ	*UCLA Historical Journal*
VEM	*Vie et Milieu*
WARC	*World Archaeology*
WDEV	*World Development*
ZDMG	*Zeitschrift d. deutsch. morgenländischen Gesellschaft*
ZFDZ	*Zeitschrift für die Zuckerindustrie*
ZUCKERIND	*Zuckerindustrie*

A. CHINESE AND JAPANESE BOOKS BEFORE +1800, AND ALL GAZETTEERS

Each entry gives particulars in the following order:

(*a*) title, alphabetically arranged, with characters;
(*b*) alternative title, if any;
(*c*) translation of title;
(*d*) cross-reference to closely related book, if any;
(*e*) dynasty;
(*f*) date as accurate as possible;
(*g*) name of author or editor, with characters;
(*h*) title of other book, if the text of the work now exists only incorporated therein; or, in special cases, references to sinological studies of it;
(*i*) references to translations, if any, given by the name of the translator in Bibliography C;
(*j*) notice of any index concordance to the book if such a work exists;
(*k*) reference to the number of the book in the *Tao Tsang* catalogue of Wieger (6), if applicable;
(*l*) reference to the number of the book in the *San Tsang* (Tripitaka) catalogues of Nanjio (1) and Takakusu & Watanabe, if applicable.
(*m*) location of the copy of gazetteers and other select books which have been consulted; this information is supplied for purposes of reference, and does not imply that the copy used bears unique features.

Dates for gazetteers refer to the date of the preface, unless otherwise indicated.

Words which assist in the translation of titles are added in round brackets.

Alternative titles or explanatory addition to the titles are added in square brackets.

Where there are any differences between the entries in these bibliographies and those in earlier Vols., the information here given is to be taken as more correct.

An interim list of references to the editions used in the present work, and to the *tshung-shu* collections in which books are available, has been given in Vol. 4, pt. 3, pp. 913ff., and is available as a separate brochure.

ABBREVIATIONS

C/Han	Former Han.
E/Wei	Eastern Wei.
H/Han	Later Han.
H/Shu	Later Shu (Wu Tai).
H/Thang	Later Thang (Wu Tai).
H/Chin	Later Chin (Wu Tai).
S/Han	Southern Han (Wu Tai).
S/Phing	Southern Phing (Wu Tai).
J/Chin	Jurchen Chin.
L/Sung	Liu Sung.
N/Chou	Northern Chou.
N/Chhi	Northern Chhi.
N/Sung	Northern Sung (before the removal of the capital to Hangchow).
N/Wei	Northern Wei.
S/Chhi	Southern Chhi.
S/Sung	Southern Sung (after the removal of the capital to Hangchow).
W/Wei	Western Wei.

An-Phing Hsien Tsa Chi 安平縣雜紀.
Miscellaneous Records of An-Phing County [Taiwan].
Chhing, late 19th century.
Author unknown.
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The Classification and Identification of Things.
Sekiseikan edition, Osaka, +1763.
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Chang-Chou Fu Chih 漳州府志.
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Comp. Yüan Yeh-Ssu 袁業泗; eds. Liu Thing-Hui 劉庭蕙 *et al.*
Naikaku Bunko, Tokyo.

Chang-Phu Hsien Chih 漳浦縣志.
Gazetteer of Chang-Phu County [Fukien].
Chhing, +1700.
Chhên Ju-Hsien 陳汝咸, Lin Têng-Hu 林登虎 *et al.*
Tōyō Bunko, Tokyo.

Chao-Chhing Fu Chih 肇慶府志.
Gazetteer of Chao-Chhing Prefecture [Kuang-Tung].
Ming, +1640.
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Chhing, +1673.
Shih Shu-Chün 史樹駿 *et al.*
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Chhing, 1832 (enlarged and revised edition of +1761 edition).
Chhêng Phêng-Li 程鵬里 *et al.*

Chêng-Ho Hsien Chih (cont.)
Copy in Tōyō Bunko, Tokyo.
Chêng Lei Pei-Yung Pên Tshao.
See *Chhung-Hsiu Chêng-Ho Ching-Shih Chêng Lei Pei-Yung Pên Tshao.*
Chha Ching 茶經.
The Manual of Tea.
Thang, *c.* +770.
Lu Yü 陸羽.
Chhang-Lo Hsien Chih 長樂縣志.
Gazetteer of Chhang-Lo County [Fukien].
Ming, +1503.
Comp. Wang Huan 王渙; eds. Liu Tsê-Ho 劉則和 & Phan Yüan 潘援.
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Chhing, +1747.
Lü Su-Kao 呂肅高, Chang Hsiung-Thu 張雄圖 *et al.*
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Chang Hsüan 張鉉 Comp.
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[Annotations to the Poetry of Su Tung-Pho by Shih Yüan-Chih 施元之, Shih Su 施宿 & Ku Hsi 顧禧].
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A General Gazetteer of Imperial Vietnam
Vietnamese Imperial decree for compilation issued in 1865, completed in 1882.
Comp. Cao Xuân Dục 高春育 *et al.*
Edition edited and published by the Indo Shina Kenkyūkai, Tokyo, 1941.

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Wang Ying-Tsêng 王瑛曾 *et al.*
Textual refs. to *Thai-Wan Wên Hsien Tshung Khan*, no. 124, Thai-Wan Yin Hang, Taipei, 1961.

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Gazetteer of Fu-Chou Prefecture [Fukien].
Ming, +1613.
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Fu-Chou Fu Chih 撫州府志.
Gazetteer of Fu-Chou Prefecture [Chiang-Hsi].
Ming, +1554.
Comp. Hsü Da-Ching 許大經 *et al.*
Textual refs. to the handcopied manuscript held at the Tōyō Bunko, Tokyo, made from the printed edition in the collection of the Imperial Household Agency 宮內廳, Tokyo.

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Gazetteer of Fu-Chou Prefecture [Chiang-Hsi].
Chhing, +1688.
Comp. Tseng Ta-Shêng 曾大升 *et al.*
Naikaku Bunko, Tokyo.

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A Complete Book Concerning Happiness and Benevolence.
Chhing, completed +1694 and first published +1699.
Huang Liu-Hung 黃六鴻.
Textual refs. are to 1850 *Kunyaku* 訓譯 edition by Obata Yukihiro 小畑行簡 (facsimile reprint, Kyūko Shoin, Tokyo, 1973).
English translation by Djang Chu (*t*).

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Gazetteer of Fu-Kou County [Ho-Nan].
Chhing, 1833.
Wang Tê-Ying 王德瑛.
Tōyō Bunko, Tokyo.

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Chhing, 1893.
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Ming, +1593.
Comp. Shih Chhi-Chhin 史起欽, Lin Tzu-Hsieh 林子燮.
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Hai-Chhêng Hsien Chih 海澄縣志.
Gazetteer of Hai-Chhêng County [Kuang-Tung].
Chhing, +1762.
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Gazetteer of Han Sub-Prefecture [Ssu-Chhuan].
Chhing, 1812 (comp.), 1817 (published), 1833 revised publication.
Liu Chhang-Kêng 劉長庚, Hou Chao-Yüan 候肇元, Chang Huai-Ssu 張懷泗 *et al.*
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Mirror of the Manchu Language, by the Emperor.
Chhing, +1708.
Though the text is in Manchu only, it is referred to in Chinese as the *Yü-Chih Chhing Wen Chien* 御製清文鑑.

Han I Araha Nonggime Toktobuha Manju Gisun I Buleku Bithe
Yü-Chih Tseng-Ting Chhing Wen Chien 御製增訂清文鑑.
Mirror of the Manchu Language published with additions under Imperial superintendence.
Chhing, preface +1778.
This is a revised and enlarged version of *Han I Araha Manju Gisun I Buleku Bithe* of +1708.

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Gazetteer of Ho-Chhuan County [Ssu-Chhuan].
Republic, 1920.
Cheng Hsien-Shu 鄭賢書, Chang Sên-Khai 張森楷 *et al.*

Ho-Ching Shih Chi 和靖詩集.
The Collected Poems of Lin Phu.
Northern Sung.
Lin Phu 林逋 (+967 to +1028).
Textual refs to *SPPY*, Chi-Pu, Sung Pieh-Chi.

Honchō Shokkan 本朝食鑑.
Japanese Alimentotherapy.
Edo, +1697.
Hitomi Hitsudai 人見必大 (Ono 小野).
See annotated translation of Shimada (*1*).

Hou Han Shu 後漢書.
History of the Later Han Dynasty [+25 to +220].
L/Sung, +450.
Fan Yeh 范曄. The monograph chapters by Ssuma Piao 司馬彪 (d. +305), with commentary by Liu Chao 劉昭 (*c.* +570), who first incorporated them into the work.
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Miscellaneous Records of the Western Capital.
Liang or Chhen, mid +6th century.
Attrib. Liu Hsin 劉歆 (C/Han) or Ko Hung 葛洪 (Chin), but probably Wu Chün 吳均 (Liang).
In *Chin Tai Mi Shu* (津逮秘書).

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Gazetteer of Hsi-Ning County [Kuang-Tung].
Chhing, 1830.
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Hsieh Lu 蟹錄.
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Chhing, date unknown.
Sun Chih Lu 孫之騄.
Included in *Chhing Chhuan Pa Shih.*

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Gazetteer of Hsin-Hsing County [Kuang-Tung].
Chhing, +1758
Liu Fang 劉芳 *et al.*
Naikaku Bunko, Tokyo.

Hsin Hsiu Pên Tshao 新修本草.
The New [lit. Newly Improved] Pharmacopoeia.
Thang, +659.
Ed. Su Ching (Su Kung) 蘇敬 (蘇恭) and a commission of 22 collaborators under the direction first of Li Chi 李勣 and Yü Chih-Ning 于志寧, then of Chhangsun Wu-Chi 長孫無忌. This work was afterwards commonly but incorrectly known as *Thang Pen Tshao.* It was lost in China, apart from MS fragments at Tunhuang, but copied by a Japanese writer in +731 and preserved incompletely in Japan.
1981 edition by Shanghai Ku Chi Chu Pan Shê.

Hsin-Hui Hsien Chih 新會縣志.
Gazetteer of Hsin-Hui County [Kuang-Tung].
Chhing, +1690.
Chia Lo-Ying 賈雒英, Hsüeh Chhi-Chiao 薛起蛟 *et al.*
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Gazetteer of Hsin-Hui County [Kuang-Tung].
Chhing, 1841.
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Tōyō Bunko, Tokyo.

Hsin-Ning Hsien Chih 新寧縣志.
Gazetteer of Hsin-Ning County [Kuang-Tung].
Chhing, +1738 (compiled), 1804 (supplemented and published).
Wang Hao 王暠, Chhên Fên 陳份 *et al.*
Seikadō Bunko, Tokyo.

Hsin-Ning Hsien Chih 新寧縣志.
Gazetteer of Hsin-Ning County [Kuang-Tung].
Chhing, 1839.
Chang Shên 張深, Tsêng Chhao 曾釗 *et al.*
Tōyō Bunko.

Hsin Thang Shu 新唐書.
New History of the Thang Dynasty [+618 to +906].
Sung, +1061.
Ouyang Hsiu 歐陽修 & Sung Chhi 宋祁.
Cf. des Rotours (*1*), (*2*); Pfizmaier (66–74).
For translations of passages see the index of Frankel (*1*).
Yin-Tê Index, no. 16.
Textual refs. to Chung-Hua Shu Chü 1975 edition.

Hsing Chha Shêng Lan 星槎勝覽.
Triumphant Visions of the Starry Raft [accounts of the voyages of Chêng Ho, whose ship, as carrying an ambassador, is thus styled].
Ming, +1436.
Fei Hsin 費信.
1939 annotated edition by Fêng Chheng-Chûn 馮承鈞; reprinted by Chhang-Sha Shang Wu Yin Shu Kuan.

Hsing-Hua Fu Chih 興化府志.
Gazetteer of Hsing-Hua Prefecture [Fukien].
Ming, +1503.
Chou Ying 周瑛, Huang Chung-Chao 黃仲昭 *et al.*
1871 reprint in Tōyō Bunko.

Hsing-Hua Fu Chih 興化府志.
Gazetteer of Hsing-Hua Prefecture [Fukien].
Ming, +1575.
Comp. Lü I-Ching 呂一靜; ed. Khang Ta-Ho 康大和.
Naikaku Bunko, Tokyo.

Hsing-Hua Hsien Hsin Chih 興化縣新志.
The New Gazetteer of Hsing-Hua County [Chiang-Su].
Ming, +1591.
Ouyang Tung-Fêng 歐陽東鳳 *et al.*
Sonkeikaku Bunko, Tokyo.

Hsiu-Shih Lu 髹飾錄.
A Record of Lacquer Painting.
Ming, approximately Lung-Chhing period (+1567 to +1572).
Huang Chhêng 黃成 or perhaps Huang Ping-Sha 黃平沙.
Annotations by Yang Ming 楊明 probably about +1625.
Only survived in two manuscripts held by the Tokyo National Museum. Satō Taketoshi (in Satō (*2*)) has shown that the Tokugawa copy predated the Kenkadō copy upon which all modern printed editions are based.

Hsü Kao Sêng Chuan 續高僧傳.
Further Biographies of Eminent (Buddhist) Monks [cf. *Kao Sêng Chuan* and *Sung Kao Sêng Chuan*].
Thang, +660.
Tao-Hsüan 道宣.
TW/2060. Textual refs. to the Ming edition of +1610 to +1611 by the Ching Shan Chi Chao An 徑山寂照庵.

Hsü-Wen Hsien Chih 徐聞縣志.
Gazetteer of Hsü-Wen County [Kuang-Tung].
Chhing, +1687 (manuscript).
Yan Ju-Thai 閻如玠 *et al.*
Textual refs. to copy in National Library, Peking.

Hsüeh Chai Chan Pi 學齋佔畢.
Glancing into Books in a Learned Studio.
Sung, +13th century.
Shih Shêng-Tsu 史繩祖.

Hsüeh Chin Thao Yüan 學津討原.
Searching for the Origin of the Transmission of Learning.
Chhing, 1805.
Ed. Chang Hai-Phêng 張海鵬.

Hua Hsien Chih 花縣志.
Gazetteer of Hua County [Kuang-Tung].
Chhing, +1687.
Wang Yung-Ming 王永名, Huang Shih-Lung 黃士龍, Huang Yü 黃鬱 *et al.*
1866 reprint in Tōyō Bunko, Tokyo.

Hua-Yang Hsien Chih 華陽縣志.
Gazetteer of Hua-Yang County [Ssu-Chhuan].
Chhing, 1816.
Wu Kung 吳鞏, Tung Chun 董淳, Phan Shih-Thung 潘時彤 *et al.*
Tōyō Bunko, Tokyo.

Hui-An Hsien Chih 惠安縣志.
Gazetteer of Hui-An County [Fukien].
Ming, +1530.
Mo Shang-Chien 莫尙簡, Chang Yüeh 張岳 *et al.*
Hōsa Bunko, Nagoya.

I Lin 易林.
Forest of Symbols of the (Book of) Changes [for divination].
C/Han, *c.* −40.
Chiao Kan 焦贛.

I Wu Chih 異物志.
Record of Strange Things.
See *Chiao-Chou IWC* (Yang Fu), *Nan I IWC* (Yang Fu).

Ka-I Hentai 華夷變態.
Conditions Accompanying the Transition from the Ming to the Barbarian Chhing.
Edo, +1674 preface, but it records testimonies taken from Chinese ships calling at Nagasaki from +1644 to +1717.
Hayashi Harunobu 林春勝 & Hayashi Nobuatsu 林信篤.
Textual refs. to Tōyō Bunko Sōkan edition, Tokyo, 1958.

Kansha Ki 甘蔗記.
An Account of Sugarcane.
Edo, +1764.
Gotō Rishun 後藤梨春.
Preface and appendix Katsuragawa Kuninori 桂川國訓.
Manuscript held at University of Tokyo Library.

Kansha Zōsei Den 甘蔗造製傳.
A Record of Sugarcane [and Sugar] Manufacturing.
Edo, +1760.
Tamura Ransui (Genyū) 田村藍水 (元雄).
Manuscript written in Tamura's own hand held by the Kyōu Shooku 杏雨書屋, Osaka.

Kao Sêng Chuan 高僧傳.
Biographies of Outstanding (Buddhist) Monks [especially those noted for learning and philosophical eminence].
Liang, between +519 and +554.
Hui-Chiao 慧皎.

Kao Sêng Chuan (cont.)
TW/2059
Kao-Yao Hsien Chih 高要縣志.
Gazetteer of Kao-Yao County [Kuang-Tung].
Chhing, +1673.
Than Huan 譚桓, Liang Têng-Yin 梁登胤 *et al.*
Naikaku Bunko, Tokyo.
Khâm Định Đại Nam Hội Điển Sự' Lệ 欽定大南會典事例.
Collected Statutes of Vietnam with Precedents Compiled by Imperial Order.
Imperial decree for compilation issued in 1843 and publication finishing sometime after 1852.
Tōyō Bunko, Tokyo.
Kuang Chih 廣志.
Extensive Records of Remarkable Things.
Chin, late +4th century.
Kuo I-Kung 郭義恭.
Edition in *Yü Han Shan Fang Chi I Shu.*
Kuang-Chou Fu Chih 廣州府志.
Gazetteer of Kuang-Chou Prefecture [Kuang-Tung].
Chhing, +1759.
Chin Lieh 金烈 *et al.*
Seikadō Bunko, Tokyo.
Kuang-Chou Fu Chih 廣州府志.
Gazetteer of Kuang-Chou Prefecture [Kuang-Tung].
Chhing, 1879.
Comp. Tai Chao-Chen 戴肇辰, Shih Chhêng 史澄 *et al.*
Kuang-Tung Hsin Yü 廣東新語.
New Descriptions of Kuang-Tung Province.
Chhing, preface dated 1700.
Chhü Ta-Chün 屈大均.
Textual refs. to the 1985 reprint by Chung Hua Shu Chü, Peking.
Kuang-Tung Thung Chih 廣東通志.
Comprehensive Gazetteer of Kuang-Tung Province.
Ming, +1561.
Huang Tso 黃佐 *et al.*
Naikaku Bunko, Tokyo.
Kuang-Tung Thung Chih 廣東通志.
Comprehensive Gazetteer of Kuang-Tung Province.
Chhing, +1697.
Chin Kuang-Tsu 金光祖 *et al.*
National Diet Library, Tokyo.
Kuang-Tung Thung Chih 廣東通志.
Comprehensive Gazetteer of Kuang-Tung Province.
Chhing, +1731.
Hao Yü-Lin 郝玉麟 *et al.*
Tōyō Bunko.
Kuang-Tung Thung Chih 廣東通志.
Comprehensive Gazetteer of Kuang-Tung Province.
Chhing, 1822.
Juan Yüan 阮元 *et al.*
Kuang-Yang Tsa Chi 廣陽雜記.
Collected Miscellanea of Master Kuang-Yang (Liu Hsien-Thing).
Chhing, *c.* +1695.
Liu Hsien-Thing 劉獻廷.
Textual refs. to edition in Phan Tsu-Yin (*t*)
Kuang-Yüan Hsien Chih 廣元縣志.
Gazetteer of Kuang-Yüan County [Ssu-Chhuan].
Chhing, +1757.
Chang Kêng-Mo 張庚謨 *et al.*
Tōyō Bunko, Tokyo.
Kuei-Hsin Tsa Chih 癸辛雜識.
Miscellaneous Notes From the Kuei-Hsin Quarter.
Sung, *c.* +1298.
Chou Mi 周密.
Edition in *Hsüeh Chin Thao Yüan,* 19 學津討原.
Kuei-Hua Hsien Chih 歸化縣志.
Gazetteer of Kuei-Hua County [Fukien].
Ming, +1516.
Comp. Yang Chin 楊縉.
Library of Congress microfilm of former Pei-Phing Library copy.
Kuei-Hua Hsien Chih 歸化縣志.
Gazetteer of Kuei-Hua County [Fukien].
Ming, +1614.
Chao Hsien-Chang 周憲章.
National Diet Library, Tokyo.
Kuei-Shan Hsien Chih 歸善縣志.
Gazetteer of Kuei-Shan County [Hui-Chou Prefecture, Kuang-Tung].
Chhing, 1881.
Chang Shou-Phêng 章壽彭, Lu Fei 陸飛 *et al.*
Tōyō Bunko, Tokyo.
Kyūyō 球陽.
The Ryūkyū Islands.
Shō, +1745.
Tei Heitetsu 鄭秉哲 *et al.*
Reprint by Kyūyō Kenkyūkai (*t*)

Lao Hsüeh An Pi Chi 老學庵筆記.
Notes from the Hall of Learned Old Age.
Sung, *c.* +1190.
Lu Yu 陸游.
Lei-Chou Fu Chih 雷州府志.
Gazetteer of Lei-Chou Prefecture [Kuang-Tung].
Chhing, 1811.
Comp. Lei Hsüeh-Hai 雷學海; ed. Chhên Chhang-Chhi 陳昌齊.
Tōyō Bunko, Tokyo.
Lien-Thing Tsang Shu Shih-Êrh Chung 棟亭藏書十二種.
Twelve works in the Collection of Tshao Yin (Liên-Thing).
Chhing, +1706.
Ed. Tshao Yin 曹寅.
Textual refs. to the 1921 facsimile edition by Shang-Hai Ku Shu Liu Thung Chhu 上海古書流通處.

Lin-An Chih 臨安志.
Gazetteer of Lin-An [Chekiang].
Sung, +1265 to +1274.
Comp. Chhien Shuo-Wên 潛說文.
Sung Yüan Ti Fang Chih Tsung Shu, vol. 7, Chung Kuo Ti Chih Yen Chiu Hui, Taipei, 1978.

Ling Nan Tsa Chi 嶺南雜記.
Miscellaneous Records of Things South of the Passes.
Chhing, later +17th century.
Wu Chên-Fang 吳震方 (*chin-shih* of +1679).
SL, hou-chi 說鈴後集.

Liu-Chhiu Kuo Chih Lüeh 琉球國志略.
Account of the Liu-Chhiu Islands.
Chhing, +1757.
Chou Huang 周煌.
Chou Huang and Chhüan Khuei 全魁 were envoys there +1756 to +1757 and were accompanied by Wang Wên-Chih 王文治, the famous poet and calligrapher.

Lo-Chhuan Chih 羅川志.
Gazetteer of Lo-Chhuan [Fukien].
Ming, +1545.
Kao Hsiang 高相.
Library of Congress microfilm of former Pei-Phing Library copy.

Lo-Fou Shan Chih Hui Pien 羅浮山志會編.
A Gazetteer of Lo-Fou Mountain (north of Canton).
Chhing, +1717 (but based on older histories).
Thao Ching-I 陶敬益.

Lo-Yüan Hsien Chih 羅源縣志.
Gazetteer of Lo-Yüan County.
Chhing, 1831.
Lu Fêng-Chhin 盧鳳琴, Lin Chhun-Po 林春溥 *et al.*
Tōyō Bunko, Tokyo.

Lung-Yen Chou Chih 龍巖州志.
Gazetteer of Lung-Yen Sub-Prefecture [Fukien].
Chhing, 1830 (compiled), 1835 (published).
Phêng Yen-Thang 彭衍堂, Yüan Hsi-Yeh 袁曦業, Chhên Wên-Hêng 陳文衡 *et al.*
Seikadō Bunko, Tokyo.

Lung-Yen Hsien Chih 龍巖縣志.
Gazetteer of Lung-Yen County [Fukien].
Ming, +1558.
Thang Hsiang 湯相 *et al.*
Library of Congress microfilm of former Pei-Phing Library copy.

Mao-Ming Hsien Chih 茂名縣志.
Gazetteer of Mao-Ming County [Kuang-Tung].
Chhing, 1819.
Chhin Yüan 秦沅, Wang Hsün-Chhen 王勳臣, Wu Hui-Hsü 吳繪敍 *et al.*
Tōyō Bunko, Tokyo.

Mao-Ming Hsien Chih 茂名縣志.
Gazetteer of Mao-Ming County [Kuang-Tung].
Chhing, 1888.
Chêng Yeh-Chhung 鄭業崇, Hsü Ju-Shao 許汝韶 *et al.*
Tōyō Bunko, Tokyo.

Mêng Chhi Pi Than 夢溪筆談.
Dream Pool Essays.
Sung, +1086, last supplement dated +1091.
Shên Kua 沈括.
Ed. Hu Tao-Ching (*1*); cf. Holzman (*1*)

Mêng Liang Lu 夢粱錄.
Dreaming of the Capital while the Millet is Cooking [description of Hangchow towards the end of the Sung].
Sung, +1275.
Wu Tzu-mu 吳自牧.
Chih Pu Tsu Chai Tshung Shu 知不足齋叢書, 28, Shanghai ed., 1921.

Min Pu Su 閩部疏.
Records of Fukien.
Ming, preface +1586.
Wang Shih-Mao 王世懋.
Textual refs. to photolithographic reproduction in *Chung-Kuo Fang-Chih Tshung-Kan*, no. 243, Taipei, 1975.

Min Shu 閩書.
The Book of Min [Fukien].
Ming, +1631.
Ho Chhiao-Yüan 何喬遠.
Naikaku Bunko, Tokyo.

Ming I Pieh Lu 名醫別錄.
Additional Records of Famous Physicians on Materia Medica.
Ascr. Liang, *c.* +510.
Attrib. Thao Hung-Ching 陶弘景.
Extant only in quotations.

Mu Mien Phu 木棉譜.
Treatise on Cotton.
Chhing, +18th century.
Chhu Hua 褚華.
Textual refs. to reprint in *Shanghai Chang Ku Tsung Shu* 上海掌故叢書, Shanghai, 1935.

Nan-Ao Chih 南澳志.
Gazetteer of Nan-Ao [Kuang-Tung].
Chhing, +1783.
Chhi Yu-Chhung 齊羽中 *et al.*
Tōyō Bunko, Tokyo.

Nan-Ching Hsien Chih 南靖縣志.
Gazetteer of Nan-Ching County [Fukien].
Ming, +1599.
Comp. Chhên Tsung-Yü 陳宗愈; eds. Wang Jên-Phin 王人聘 *et al.*
Library of Congress microfilm of former Pei-Phing Library copy.

Nan Fang Tshao Mu Chuang 南方草木狀.
A Prospect of the Plants and Trees of the Southern Regions.
Chin, +304.
Hsi Han 嵇含.
Textual refs. to edition in *SF*.
Tr. Li, H. L. (12).

Nan-Hai Hsien Chih 南海縣志.
The Gazetteer of Nan-Hai County [Kuang-Tung].
Chhing, +1691.
Kuo Êrh-Shih 郭爾祀 Hu Yün-Kho 胡雲客 *et al.*
Naikaku Bunko, Tokyo.

Nan I I Wu Chih 南裔異物志.
Strange Things from the Southern Borders.
H/Han, *c.* +90.
Yang Fu 楊孚.
Perhaps the earlier title of his *Chiao-Chou I Wu Chih*, q.v.
Extant only in quotations.

Nan-Khang Hsien Chih 南康縣志.
Gazetteer of Nan-Khang County [Chiang-Hsi].
Chhing, +1710.
Shên Yü-Lai 申毓來, Sung Yü-Lang 宋玉朗.
Naikaku Bunko, Tokyo.

Nan-Phing Hsien Chih 南平縣志.
Gazetteer of Nan-Phing County.
Chhing, 1872, supplemented edition.
Yang Kuei-Sên 楊桂森, Ying Tan-Chao 應丹詔 *et al.*
Tōyō Bunko, Tokyo.

Nan Shih 南史.
History of the Southern Dynasties [Nan Pei Chhao period, +420 to +589].
Thang, *c.* +670.
Li Yen-Shou 李延壽.
For translations of passages see the index of Frankel (1).

Nihon Sankai Meibutsu Zue 日本山海名物圖會.
Collected Illustrations of Famous Products of the Mountains and Seas of Japan.
Japan (Tokugawa), Osaka, +1754.
Hirase Tessai 平瀨徹齋.
Illus. by Hasegawa Mitsunobu 長谷川光信 & Chigusaya Shinemon 千種屋新右衛門.
Facsimile reprint with introductory notes, Meicho Kankōkai, Tokyo, 1969.

Ning-Hua Hsien Chih 寧化縣志.
Gazetteer of Ning-Hua County [Fukien].
Chhing, +1684.
Li Shih-Hsiung 李世熊 *et al.*
Seikadō Bunko, Tokyo.

Ning-Tê Hsien Chih 寧德縣志.
Gazetteer of Ning-Tê County [Fukien].
Ming, +1538.
Comp. Min Wên-Chên 閔文振.
Library of Congress microfilm of former Pei-Phing Library copy.

Ning-Tê Hsien Chih 寧德縣志.
Gazetteer of Ning-Tê County [Fukien].
Ming, +1591.
Comp. Shu Ying-Yüan 舒應元; eds. Chhên Kuan 陳琯 *et al.*
Manuscript copy in Tōyō Bunko, Tokyo.

Nōgyō Zensho 農業全書.
Collected Writings on Agriculture.
Edo, +1697.
Miyazaki Yasusada 宮崎安貞.

Nung Chêng Chhüan Shu 農政全書.
Complete Treatise on Agricultural Administration.
Ming, composed +1625 to +1628, printed +1639.
Hsü Kuang-Chhi 徐光啓; ed. Chhên Tzu-Lung 陳子龍.
Textual refs. to the new annotated ed., published in Shanghai in 1979, Shih Shêng-Han (8).

Nung Sang Chi Yao 農桑輯要.
Fundamentals of Agriculture and Sericulture.
Yüan, +1273.
Preface by Wang Phan 王磐. Imperially commissioned and produced by the Agricultural Extension Bureau 司農司.
Probable editor, Mêng Chhi 孟祺.
Probable later editors, Chhang Shih-Wên (*c.* +1286) 暢師文, Miao Hao-Chhien (*c.* +1318) 苗好謙, +1339 edition.
Textuals refs. to photolithographic edition by Shanghai Thu Shu Kuan, 1979.

Nung Shu 農書.
Agricultural Treatise.
Yüan, +1313.
Wang Chên 王禎.
Textual refs. to the 22 *chüan* Palace ed. of +1783, prefaced +1774, and to Wang Yü-Hu (8).

Nung Thien Yü Hua 農田餘話.
Talks on Farming the Fields.
Ming, +14th century, probably with later additions.
Chhang-Ku Chên-I 長谷眞逸.

Ou-Ning Hsien Chih 甌寧縣志.
Gazetteer of Ou-Ning County [Fukien].
Chhing, +1694.
Têng Chhi-Wên 鄧其文 *et al.*
Tōyō Bunko, Tokyo.

Pa Min Thung Chih 八閩通志.
Gazetteer of Fukien Province.
Ming, +1491.
Huang Chhung-Chao 黃仲昭 *et al.*
Naikaku Bunko, Tokyo.

Pen Tshao Ching Chi Chu 本草經集注.
Collected Commentaries on the Classical Pharmacopoeia of the Heavenly Husbandman.
+492.
Thao Hung-Ching 陶弘景.

Pên Tshao Kang Mu 本草綱目.
The Great Pharmacopoeia or The Pandects of Pharmaceutical Natural History.
Ming, +1596.
Li Shih-Chên 李時珍.
Paraphrased and abridged, tr. Read and collaborators (1–7) and Read and Pak (1), with indexes.

Pên Tshao Kang Mu (cont.)
Textual refs. are to the Jen Min Wei Shêng Chu Pan Shê edition, 1982.
Pên Tshao Méng Chhüan 本草蒙筌.
Enlightenment on Pharmaceutical Natural History.
Ming, +1565.
Chhen Chia-Mo 陳嘉謨.
Text. refs. to the +1628 enlarged and supplemented illustrated edition in the University of Tokyo Library.
Pên Tshao Thu Ching 本草圖經.
Illustrated Pharmacopoeia or Illustrated Treatise of Pharmaceutical Natural History.
Sung, +1061.
Su Sung 蘇頌 *et al.*
Now preserved only in numerous quotations in the later pandects of pharmaceutical natural history.
Pên Tshao Yen I 本草衍義.
Dilations upon Pharmaceutical Natural History.
Sung, preface +1116, printed +1119, repr. +1185, +1195.
Khou Tsung-Shih 寇宗奭.
Phan-Yü Hsien Chih 番禺縣志.
Gazetteer of Phan-Yü County [Kuang-Tung].
Chhing, +1686.
Kung Hsing-Lien 孔興漣 *et al.*
Naikaku Bunko, Tokyo.
Phan-Yü Hsien Chih 番禺縣志.
Gazetteer of Phan-Yü County [Kuang-Tung].
Chhing, +1871.
Li Fu-Thai 李福泰 and Shih Chhêng 史澄 *et al.*
Tōyō Bunko, Tokyo.
Phing-Yüan Hsien Chih 平遠縣志.
Gazetteer of Phing-Yüan County [Kuang-Tung].
Chhing, 1820.
Lu Chao-Ao 盧兆鰲 *et al.*
Tōyō Bunko, Tokyo.
Phu Biên Thup Lục 撫邊雜錄.
Miscellaneous Records of Pacifying the Border [i.e. Quang-Nam after attack by Trinh army].
Lê, +1776.
Lê Quý-Đôn 黎貴惇(尤厚).
Textual refs. to Jinbun Kagaku Kenkyūjo (Kyōto) photocopy made from manuscript held in France.
Phu-Ning Hsien Chih Lüeh 普寧縣志略.
Brief Gazetteer of Phu-Ning County [Kuang-Tung].
Ming, +1610.
Juan I-Lin 阮以臨, Huang Ping-Chung 黃秉中 *et al.*
Manuscript in the possession of the former Pei-Phing Library.
Pien Min Thu Tsuan 便民圖纂.
A Handy Illustrated Compendium for the People.
Ming, +1502, repr. +1552 and +1593.
Khuang Fan 鄺璠.
Textual refs. to photolithographic edition by Chung Hua Shu Chü, Shanghai, 1959.
Po Chai Phien 泊宅編.
A Compilation Made at Po Chai Village.
Sung, +1125.
Fang Shao (+1066 to +1141) 方勺.
Citations from edition in *Pai Hai* 稗海.
Po-Lo Hsien Chih 博羅縣志.
Gazetteer of Po-Lo County [Kuang-Tung].
Chhing, +1687.
Thao Ching 陶敬.
Naikaku Bunko, Tokyo.

Ri Jo Sil Rok 李朝實錄.
The Veritable Records of the Ri Dynasty.
Ri Dynasty, +1392 to 1863.
Photolithographic edition published by Gakushūin Daigaku, Tōyō Bunka Kenkyūjo, Tokyo, 1953–1967.
Ryūkyū Sanbutsu Shi 琉球產物志.
An Account of Products of the Ryūkyū Kingdom.
Edo, preface dated +1771.
Tamura Genyū 田村元雄.
Manuscript with colour illustrations held by the National Diet Library, Tokyo.

San Nung Chi 三農紀.
Records of the Three Departments of Agriculture.
Chhing, preface +1760.
Chang Tsung-Fa 張宗法.
Records of agricultural and handicraft practices in Ssu-Chhuan.
Textual refs. to edition printed by Li Chao Shu Wu 黎照書屋 held by East Asian History of Science Library, Cambridge.
San Shan Chih 三山志.
Gazetteer of San Shan [Fukien].
Sung, +1182.
Liang Kho-Chia 梁克家.
Sung Yüan Ti Fang Chih Tsung Shu, vol. 12, Chung Kuo Ti Chih Yen Chiu Hui, Taipei, 1978.
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Than Huan 譚桓, Liang Tsung-Tien 梁宗典 *et al.*
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Comp. Hsü Jen 許仁 & Chiang Khung-Yang 蔣孔暘.
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Chhing, +1780.

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Chhing, +1736.
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Account of Taiwanese geography, history, politics, economics, customs, and aborigines based on knowledge gained when the author was dispatched to the island in +1722.
Textual refs. to reprint in *Taiwan Wên Hsien Tsung Khan* series no. 4, Thai-wan Yin Hang, 1957.
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Sung, +976 to +983.
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Sung, +983.
Ed. Li Fang 李昉.
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Gazetteer of Thai-Wan Prefecture [Taiwan].
Chhing, after +1691.
Chiang Yü-Ying 蔣毓英.
Only known copy of the original edition in Shanghai Library 上海圖書館.
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Sung, +961.
Wang Phu 王溥.
Cf. des Rotours (*2*), p. 92.
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Monograph on Sugar Candy.
Sung +1119 to +1154.
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Ming, +1595 preface (60 *chüan* version).
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Ku Yen-Wu 顧炎武.
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Ming, +1637.
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Tr. Sun & Sun (*1*).
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Gazetteer for Thing-Chou Prefecture [Fukien].
Ming, +1637.
Comp. Thang Shih-Han 唐世涵; ed. Ma Shang-Jung 馬上榮.
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Thing-Chou Fu Chih 汀州府志.
Gazetteer for Thing-Chou Prefecture [Fukien].
Chhing, +1752.
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Thu Ching (Pên Tshao) 圖經(本草).
Illustrated Treatise (of Pharmaceutical Natural History).
See *Pên Tshao Thu Ching.*
The term *Thu Ching* applied originally to one of the two illustrated parts (the other being a *Yao Thu*) of the *Hsin Hsiu Pên Tshao* of +659 (q.v.); cf. *Hsin Thang Shu*, ch. 59, p. 21a or *TSCCIWHC*, p. 273. By the middle of the +11th century these had become lost, so Su Sung's *Pên Tshao Thu Ching* was prepared as a replacement. The name *Thu Ching Pên Tshao* was often afterwards applied to Su Sung's work, but (according to the evidence of the *Sung Shih* bibliographies, *SSIW*, pp. 179, 529) wrongly.
Thu Ching Yen I Pên Tshao 圖經衍義本草.
Illustrations (and Commentary) for the *Dilations upon Pharmaceutical Natural History* [An abridged conflation of the *Chêng-Ho* ... Cheng Lei ... Pên Tshao with the *Pên Tshao Yen I*].
Sung, *c.* +1223.
Thang Shên-wei 唐愼微, Khou Tsung-

Thu Ching Yen I Pên Tshao (cont.)
Shih 寇宗奭; ed. Hsü Hung 許洪.
TT/761; see also *Thu Ching Chi-Chu Yen I Pên Tshao.*
Cf. Chang Tsan-Chhên (*2*); Lung Po-Chien (*1*) nos. 38, 39.

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Illustrations and Collected Commentaries for the *Dilations upon Pharmaceutical Natural History.*
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Chhing, +1798.
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Seikadō Bunko, Tokyo.

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Yunnan Pharmacopoeia.
Ming, +1556.
Lan Mo 蘭茂.
Textual refs. to the 1976 reprint of 1959 edition by Yunnan Jên Min Chhu Pan Shê, Khun-Ming.

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Chhing, 1878.
Wu Ying-Lien 吳應廉, Wang Ying-Tou 王映斗 *et al.*
Tōyō Bunko, Tokyo.

Tōtsūji Kaisho Nichiroku 唐通事會所日錄.
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Tshai Shu 蔡淑 *et al.*
Naikaku Bunko, Tokyo.

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Sung, commissioned +1005, pr. +1013.
Eds. Wang Chhin-Jo 王欽若 & Yang I 楊億.
Cf. des Rotours (*2*), p. 91.

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The Wonder of the Capital [Hangchow].
Sung, +1235.
Mr Chao 趙氏 [Kuan Pu Nai Tê Weng 灌圃耐得翁; The Old Gentleman of the Water-Garden who Achieved Success Through Forbearance].
Textual refs. to 1956 edition in *Tung Ching Mêng Hua Lu Wai Ssu Chung* 東京夢華錄外四種.

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Dreams of the Glories of the Eastern Capital [Khaifeng].
S/Sung, +1148 (referring to the two decades which ended with the fall of the capital of N/Sung in +1126 and the completion of the move to Hangchow in +1135); first print +1187.
Mêng Yüan-Lao 孟元老.
1956 edition published by Shanghai Ku Tien Wen Hsueh entitled *Tung Ching Mêng Hua Lu Wai Ssu Chung* 東京夢華錄外四種.

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Chhing, +1689.
Kuo Wên-Ping 郭文炳 *et al.*
Naikaku Bunko, Tokyo.

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Collected Political Affairs of Tung-Ning [Taiwan].
Chhing, +1661 to +1683.
Author unknown.
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Tzu Chih Thung Chien 資治通鑑.
Comprehensive Mirror (of History) for Aid in Government [−403 to +959].
Sung, +1065 began compilation, +1084 completed.
Ssuma Kuang 司馬光.
Textual refs. to Chung-Hua Shu-Chü edition, 1982.

Văn Đài Loại Ngữ 芸臺類語.
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Lê, author's preface dated +1773.
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History of the (Northern) Wei Dynasty [+386 to +556].

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Ming, +1605.
Thang Jih-Chao 湯日昭 *et al.*
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General Anthology of Prose and Verse.
Liang, +530.
Ed. Hsiao Thung 蕭統 (Prince of Liang).
Commentary by Li Shan 李善 *c.* +670.
Tr. van Zach (*6*).
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The Works of Wang Wu-Hsi [i.e. Wang Feng].
Wang Fêng 王逢 (+1319 to +1388).
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Gazetteer of Wu-Hsing [Chekiang].
Sung, +1201.
Comp. Than Yueh 談鑰.
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Wu Li Hsiao Shih 物理小識.
Small Encyclopaedia of the Principles of Things.
Ming and Chhing, finished by +1643, pr. +1664.
Fang I-Chih 方以智.
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Institutions and Customs of the Old Capital (Hangchow).
Sung, *c.* +1270 (but refs. to events from about +1165 onwards).
Chou Mi 周密.
Textual refs. to 1965 edition in *Tung Ching Mêng Hua Lu Wai Ssu Chung* 東京夢華錄, 外四種.

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Chhing, +1687.
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Chhing, +1746.
Chuang Ta-Chung 莊大中.
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Yen Fan Lu 演繁露.
Extension of the String of Pearls on the Spring and Autumn Annals [on the meanings of many Thang and Sung expressions].
Sung, +1180.
Chhêng Ta-Chhang 程大昌.
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42b. FORESTRY

This contribution is dedicated with respect and gratitude to

CHHÊN JUNG

of Chin Ling University who was not prepared to accept that the Chinese people had never cared for their forests, and to

WALTER LOWDERMILK

who was prepared to learn from what he had seen in China.

AUTHOR'S NOTE

To manage a forest demands an understanding of the dynamics of vegetation growth and change, and the skill to ensure that the crop of trees will receive the care and attention it needs over many years or decades to reach a harvestable size. Forestry therefore links investigations in the natural sciences with enquiries into the way in which humans organise themselves to achieve long-term objectives, and the forester's profession may be as close to an art as it is to a science.

A study such as this one (originally written in 1986), which sets out to introduce the history in one country of a topic as diverse as 'Forestry' inevitably owes its existence not just to one named author, but to the unstinting help offered by a large number of individuals and organisations. Local officials in Hu-Nan and Inner Mongolia went to great lengths to organise field visits for me which brought the historical texts to life and confirmed that ancient management techniques still play an important role in Chinese forestry today. Meanwhile, in Britain and the United States, the Needham Research Institute, the Department of Forestry and Resource Management at the University of California at Berkeley, and the Conservation and Research Foundation of New London, Connecticut, all offered grants and assistance to ensure that I had the financial resources needed to concentrate on this work.

It has been my privilege during the years in which I have been involved in this endeavour in China and elsewhere to have worked with many scholars who enthusiastically supported me and assisted my research. My greatest debt is to the many Chinese scholars who have devoted their careers to combing through the the vast volume of classical literature to extract the scattered references to forest management. The works of the late Chhên Jung and Kan To still remain the basic sources for any research. Even with these guides, I would not have been able to move very far without the guidance of Professor Chang Chün-Chhêng of the Forestry University in Peking. Professor Chang gave me access to his unique collection of texts, and willingly spent long days introducing me to contemporary research on forest history in China. I am deeply indebted to Professor Chang who first led me to many of the sources I have used here, but I am entirely responsible for the conclusions I have drawn from them, with some of which I know that he will disagree.

In Nan-Ching, Professor Hsiung Ta-Thung and his colleagues at the Nan-Ching Forestry University facilitated access to the library collections of the former Chin Ling University, the first centre for research and teaching of forestry in modern China. I received similar assistance at the South Central College of

Forestry in Chu Chou, Hu-Nan, and at Hsia Men University in Fukien. The list of individuals who have helped me is long, and I can only mention a few by name here, but my thanks go to all who helped in any way.

Preparing and writing a study such as this one over a long period of time and at a long distance from Cambridge, inevitably meant that it contained many inconsistencies and inaccuracies. An editor's contribution is perhaps one of the least visible yet most important elements of the text. I am therefore indebted to Helen Spillett who took on the task of editing my manuscript and turning it into a book conforming to the style and format of its companions in the *Science and Civilisation in China* series.

Finally, I wish to acknowledge the patience, understanding, and moral support of those who shared an office with me over the many years I spent at Berkeley, and to all those who have read the many drafts of this study and offered their advice and criticism. Without all of you, I could not have seen it through to this stage. Thank you.

N. M.

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Peking
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(*a*) INTRODUCTION

The vegetation along the shores of the river is sad beyond compare – not a shrub, no woody growth, except for a few willows planted in the villages. As for herbaceous species, there are only a few and those are always the same. [Père Armand David, 1875][a]

When Western botanists and naturalists began to work in China in the late 19th and early 20th centuries, millenia of intensive agricultural production had so altered the landscape that it was almost impossible to visualise what it had looked like when the land was first cleared and settled. Deforestation was so serious that it prompted fears that soon 'there will not be an acre of accessible forest left in all central, southern and western China.'[b]

The image of the Chinese landscape given by early travellers is of a parched, eroded wilderness destroyed by reckless exploitation and overgrazing. Different writers found different causes, but the blame was usually placed on the shoulders of the Chinese people who were described as 'destructive', 'ruthless', or even as having an innate hatred of trees.[c] A very few observers found evidence of forest management where others had only seen small patches of trees surviving amid the destruction. Fenzel, in 1929, observed that groves of trees in southern China which were protected for geomantic reasons, were carefully managed to supply timber and to protect water catchments.[d] Ten years earlier, Lowdermilk had carried out extensive surveys of erosion and deforestation in northern China. He and his assistants discovered indigenous systems of silviculture being practised in protected temple forests, in forests owned collectively by villages and temple associations and even in densely populated suburban areas.[e]

Early attempts to trace the history of forestry and deforestation in China adopted a traditional Confucian outline of Chinese history. According to this model, forests had been protected during the age of the mythical sage kings and during the remote past of the Shang and Chou dynasties. The passing of the golden age was followed by centuries of relentless destruction, while the people suffered the terrible consequences of timber shortages, flooding and erosion.[f] Once again, it was the work of Lowdermilk which began to question this simple interpretation of events. A study of records of land use in the Wu Thai Shan[1] area of Shan-Hsi province showed that there had been periods of forest

[a] David (1), p. 148. Père David's observations here were made in the upper reaches of the Yellow River, an area which is particularly barren because of its arid climate and saline, alkaline soils.

[b] Wilson (3), vol. 1, p. 246.

[c] *Ibid.*, vol. 1, p. 247, also cf. Fortune (4), esp. pp. 177–8, and Rosenbluth (1).

[d] Fenzel (1).

[e] Jên (1), Lowdermilk (4) and Lowdermilk & Li (1).

[f] Blackwelder (1), and Têng, Shu-Chun (1), are classics in the genre.

[1] 五臺山

destruction followed by periods of protection and recovery enforced by Imperial edict.[a] The records showed that deforestation was not a relentless, irreversible process, but was affected by the changing needs and priorities of Chinese society.

(1) Sources

There is no specialised body of Chinese literature on forestry. State policy was embodied in the phrase '*chung nung*[1],' 'emphasise agriculture' and, although this often involved pious expressions of concern rather than effective actions, other forms of land use received very little attention. The official histories contain the texts of edicts prohibiting the cutting of timber in order to protect the remaining forests, but there are as many edicts reversing the prohibitions. Every dynasty had officials whose duties included the conservation of forests,[b] but these protective measures were never given the continuity and authority embodied in institutions such as the codes of Forest Law promulgated in Central Europe during the Carolingian period, or in Britain following the Norman Conquest. The student of Chinese forest history, lacking the legal documents and records which are a rich source of information on the subject in Europe, is obliged instead to glean from a variety of secondary sources.

The corpus of works on agricultural technology is perhaps the richest source of information on silviculture. These works are concerned mainly with the production of grain crops, but, by the time they were written, timber was valuable enough for trees to be planted on agricultural land, and most of them contain a section on the cultivation of trees.[c]

The *Chhi Min Yao Shu*[2], compiled by Chia Ssu-Hsieh[3] c. +535, is of great interest because it is the first extant work to have a section specifically on the subject of trees.[d] The priorities of the *Chhi Min Yao Shu* are agricultural, which explains why many of the species listed as 'trees' are woody perennials grown as economic crops for products such as dyes, spices and medicines derived from their flowers or roots. The most important timber species are elm, willow, poplar and oak, which were all grown under intensive management systems on rotations as short as three years, and as long as ten or even twenty years.

[a] Lowdermilk & Wickes (3).

[b] Wang Hsi-Liang[4] (1) and (2).

[c] Vol. 6, pt 2, pp. 47–85, describes the manuals and their contents in some detail. We will confine ourselves here to observations of particular relevance to forestry.

[d] Wang Yü-Hu[5] in his bibliography of works on agriculture says that there are records of a lost Han dynasty work in thirteen chapters, the '*Chung Shu Tsang Kuo Hsiang Tshan*[6]', 'On Planting Trees, Storing Fruit and Caring for Silkworms'. Some scholars believe this to have been the source for most of the information on silviculture in the *CMYS*. In Wang Yü-Hu (1), p. 17.

[1] 重農 [2] 齊民要術 [3] 賈思勰 [4] 王希亮 [5] 王毓瑚
[6] 種樹藏果相蠶

The Yüan dynasty *Nung Sang Chi Yao*[1], compiled by the Imperial Board of Agriculture in +1273 does not contain much original material, but it quotes from many sources which are now lost, and this makes it a valuable summary of knowledge about forestry during the medieval period. It is the first work to consider the new species and techniques from the recently settled south, with details given for planting pines and other conifers ignored by the *Chhi Min Yao Shu* or mentioned only in its section on logging. The descriptions of tree planting are characterised by labour-intensive techniques such as weeding, fertilising and careful site preparation before planting, most appropriate to plantations within agricultural systems.

A third treatise of particular interest here is the work of the late Ming savant, Jesuit convert and would-be social reformer, Hsü Kuang-Chhi[2]. The *Nung Chêng Chhüan Shu*[3] published in 1639 is a compendium of earlier knowledge, with the addition of extensive commentaries and original material by Hsü himself. The section on trees is very thorough, covering northern and southern species, with an introductory section outlining and comparing different techniques of planting and transplanting. The focus of the work is agricultural, but there is some consideration of timber as a land use in its own right, particularly in the paragraphs on *Cunninghamia lanceolata* (Lamb.) Hook, (*sha*[4]), which Hsü says is suited to mountainous areas where annual crops cannot be grown.[a]

(i) *Works on arboriculture*

In addition to these general treatises, two specialised works survive, as well as some monographs on bamboo, paulownia, and many horticultural species, especially fruit trees. The earlier of the two manuals of arboriculture is the *Chung Shu Shu*[5] compiled by Yü Tsung-Pên[6] in the late +14th century, probably during the first years of the Ming dynasty. It was formerly said to date from the +8th century, and was ascribed to Kuo Tho-Tho[7] a horticulturist whose methods of tree planting were described in a fable by the Thang essayist Liu Tsung-Yüan[8].[b] This early dating is unacceptable because there are extensive quotations from works later than the Thang dynasty, and it is not listed in any bibliographies before the Ming dynasty.

The *Chung Shu Shu* consists of a monthly calendar of planting and silvicultural tasks, followed by specialised sections on trees, bamboos and other crops including grains, legumes and vegetables. The text is once again a compilation of

[a] *NCCS*, ch. 38, p. 36a. *Cunninghamia lanceolata* has sometimes been incorrectly translated as 'Chinese fir'. 'Fir', strictly speaking, refers to the genus *Abies*, of the family *Pinaceae*, not to *Cunninghamia*, which belongs to the family *Taxodiaceae*. To avoid confusion, I will refer to it as cunninghamia, or to its Chinese name, *sha mu*. See also (*b*), (3), below on cunninghamia.

[b] *Chung Shu Kuo Tho Tho*[9], in *Liu Ho-Tung Chi*, ch. 17, pp. 305–6.

[1] 農桑輯要 [2] 徐光啓 [3] 農政全書 [4] 杉 [5] 種樹書
[6] 俞宗本 [7] 郭橐駝 [8] 柳宗元 [9] 種樹郭橐駝

existing material, and Yü Tsung-Pên does not usually acknowledge his sources. Its value lies mainly in the fact that it assembles many scattered references, and makes them accessible in a convenient format.

The 'Division of Trees and Livestock', *Shu Hsü Pu*[1], by Sung Hsü[2] was written in +1504. It consists of four chapters, in a collection including other works by the same author and by his son under the title 'Miscellany from a Mountain Lodge on Bamboo Island', *Chu Yü Shan Fang Tsa Pu*[3]. It is unusual in that it is based on the author's own experience, with very little reliance on quotations from previous works.

The first chapter opens with a discussion of silvicultural techniques. It covers transplanting and planting, irrigation and fertilising, as well as grafting, pruning and horticultural treatments for ornamentals and fruit trees. It then describes how to plant some forty-four species of timber trees and a large number of fruit trees and economic perennials.[a] Chapter two gives instructions on growing and caring for flowers, herbs and bamboos, including the regeneration of bamboos after flowering. These first two chapters are of particular interest for their practical advice on the cultivation of trees and bamboo. The last two chapters discuss grains, vegetables and livestock.

Monographs on individual species or groups of plants are fairly common. Most of them were written about flowers or horticultural species, and bamboo and paulownia are the only timber species to be so honoured. The 'Monograph on Bamboos', *Chu Phu*[4], is a very early work, dating from the Chin dynasty (between +317 and +420, ascribed to Tai Khai-Chih[5] a native of Wu-Chhang[6], Hu-Pei province. It is a listing, in quatrains, of different varieties of bamboo, their uses, and where they grow, but has little information about planting and managing bamboo. Tai Khai-Chih's work was very successful, and many later monographs were written in the same style.[b] The 'Monograph on Paulownias', *Thung Phu*[7], by Chhên Chu[8], appeared in +1049. In the preface, Chhên Chu writes that after many years spent growing paulownia and bamboo near Thung-Ling[9], An-Hui province, he had decided to record the fruits of his experience for the benefit of later generations. The monograph is a compendium of lore about paulownias, as well as a manual covering the different species and varieties (some of which are not in fact botanically related to the paulownias), cultivation, harvesting, regeneration and utilisation of the timber.

(ii) *Botanical, historical and literary sources*

Information about utilisation of forest trees can be found in botanical compendia such as the *Chhüan Fang Pei Tsu*[10], the *Chhün Fang Phu*[11], and the *Chih Wu Ming*

[a] The numbers are approximate, since some of the species are listed more than once under different names.
[b] Wang Yü-Hu (*1*), p. 310, lists four later works with the same title.

[1] 樹畜部 [2] 宋詡 [3] 竹嶼山房雜部 [4] 竹譜 [5] 戴凱之
[6] 武昌 [7] 桐譜 [8] 陳翥 [9] 銅陵 [10] 全芳備祖
[11] 群芳譜

Shih Thu Khao[1] (Wu Chhi-Chün (*1*)).[a] They were not intended to be practical manuals for gardeners or foresters, but their encyclopaedic scope means that much can be learned from them. Another indirect source for some of the more ornamental species is the literature on landscape gardening, although some of the labour-intensive procedures recommended for transplanting and pruning would have been inappropriate for larger-scale timber plantations.

The 'Local Produce', *Wu Chhan*[2] sections in the local histories (*ti-fang chih*[3]) of forested regions might be expected to give details of forestry and logging practices which would help compensate for the agricultural bias of our other sources. Unfortunately, the contents of gazetteers vary widely, depending on the interests of the compilers or editor. The 1919 Gazetteer of Nan-Phing[4] county, Fukien province, a centre of timber production at least since the sixteenth century, only lists trees to be found in the county, and says nothing about their importance to the county's economy. The 1839 Gazetteer of Tsun-I prefecture[5] in Kuei-Chou, on the other hand, gives detailed descriptions of the cultivation of several major timber species, as well as a whole chapter on oak sericulture, and another chapter on the procurement of timber to build the Imperial palaces in Peking.

The search for descriptions of forests and forestry can be extended indefinitely into the vast body of Chinese literature. Some poets wrote about their pleasure in planting trees, and occasionally included details about seeding and transplanting techniques. There are accounts in the dynastic histories of timber being brought from remote regions to the capital for construction. Collections of memorials often contain requests for prohibitions on logging from officials in regions devastated by flooding following the deforestation of water catchments. These diverse materials provide a rich supplementary source of information about the role of forests in the history of China although much still needs to be done to assemble and to analyse them.

(2) The Forest Vegetation of China

(i) *Distribution and composition of forests*

The East-Asian land mass extends from the arctic tundra and steppes of Siberia to the tropical rain forests of the Indochinese peninsula. With the exception of the Chhin-Ling[6] range which is generally accepted to be the transition belt between the deciduous and evergreen broadleaf forests, there are few natural barriers dividing the land into distinct vegetation zones in the way that the Alps divide Europe into northern and southern zones. The present boundaries

[a] See Vol. 6, pt 1, on Botany for details about these and other botanical works.

[1] 植物名實圖考 [2] 物產 [3] 地方志 [4] 南平 [5] 遵義
[6] 秦嶺

of China stretch from about 54° to about 18°N latitude.[a] In the absence of human disturbance, a continuous expanse of woodland would stretch from north to south, including all the forest types from arctic boreal forest to tropical rain forest.

The forests of China are largely confined to the eastern half of the country. Grasslands and scrub predominate in the arid west, except in mountainous areas where sufficient water is derived from winter snowfall to support coniferous forests.[b] Deforestation has severely reduced the original extent of the eastern forests, in some places leaving only small areas of relict forest as evidence of the original vegetation. It is possible to determine the species present before deforestation but there is still disagreement about their distribution, and whether they formed dense, closed forest, open woodlands, or savannah grasslands with trees along rivers and water courses.

The flora of China has long been recognised as being unusually diverse,[c] with unexpected affinities to the flora of the south-eastern United States. E. H. Wilson listed sixteen common genera including the magnolias, catalpa and tulip trees (Liriodendron), all originally endemic to both areas.[d] This disjunct distribution is the result of glaciation during the last Ice Age. Recent research shows that most of East Asia was not covered by the ice sheets which extended across the northern hemisphere. Species which had been common in Asia and across the entire American continent were eliminated from the glaciated areas, and survived only in the temperate zones of China and the south-eastern United States.[e]

A characteristic of the phytogeography of China is that some areas, usually mountainous, have a high concentration of endemic species and surviving representatives of genera or species otherwise known only from fossil records. The dawn redwood (*Metasequoia glyptostroboides* Hu et Cheng), previously known as a fossil species, was found in 1946 growing in the mountains separating Ssu-Chhuan and Hu-Pei. The Thien Mu Shan[1] range on the borders of An-Hui and Chekiang provinces is the only area in China with a native population of cryptomeria more usually known as a Japanese species,[f] and possibly some wild specimens of the ginkgo, otherwise known as a cultivated tree, the sole survivor of a common family of fossil trees. The topography of these areas allowed for sufficient micro-climatic variation to permit the survival of many species which disappeared from less sheltered environments at times of climatic

[a] This does not include the small groups of coral islands in the South China Sea.

[b] Wang Chi-Wu also notes that richer, more varied vegetation surrounds oases, dried-up lakes, and the fringes of desert basins. Wang, Chi-Wu (1), pp. 1–2, and chapter 7.

[c] See Bretschneider (10), for an exhaustive survey of European knowledge of the botany of China.

[d] Wilson (1), p. 289.

[e] See John (1), pp. 219–32, and especially the map on p. 200, for a reconstruction of the ice sheets.

[f] It is not certain whether the Chinese and Japanese *Cryptomeria* are the same species, or two different species of the same genus. See Furukoshi (1).

[1] 天目山

change. Similar centres of biological diversity, known as refugia, have been identified in South-East Asia and South America, although there is still debate about their origins.[a]

Proposed systems of vegetation classification have all identified the same major divisions in the eastern forest.[b] They recognise a northern boreal coniferous forest zone, a northern temperate broadleaf deciduous forest zone, a southern temperate mixed evergreen and deciduous broadleaf forest, and a tropical monsoon forest zone. In 1961, Wang Chi-Wu based his survey of the forests of China on plant communities, with particular emphasis on relict vegetation as an indicator of the original vegetative cover. He divided the country into twelve forest types and four non-forest types (grassland and desert).[c] He then segregated the forest types according to their geographical distribution and composition. The emphasis on plant communities makes this system difficult to use in studying human impacts on the forests, since a forest type such as the mixed mesophytic forest covers areas with a history of human settlement as different as the densely populated Yangtse basin and the remote, inaccessible mountains of Kuei-Chou.

A recent vegetation map of China prepared under the direction of Hou Hsüeh-Yü[1] divides the country into eight vegetation zones, ranging from boreal mixed deciduous and coniferous forest to 'high altitude semi-desert' (see Fig. 116 and Table 20). These zones are subdivided into over thirty vegetation types, within which plant communities have been mapped.[d] Current land use has been incorporated into the map, allowing some consideration of the distribution of vegetation with respect to the effects of human settlement and current land use.

The historical geographer Wên Huan-Jan[2] has identified five forest zones (not including the western grasslands and desert) which combine the biological factor of the dominant plant communities with the human factor of the history of exploitation of the forest. These are, the boreal forest and swamps of the Greater Hsing An Ling[3] mountains, the boreal forest of the Lesser Hsing An Ling mountains, the temperate forest of north China, the subtropical forest of central and southwestern China, and the tropical forest of southern China.[e] Wên Huan-Jan's forest zones are a useful framework for a study of the development of forestry. In Map 6 and Table 21 I have adjusted the system to allow more detail in areas where forest utilisation was most significant by introducing some subdivisions in the temperate forest of north China. The two boreal forests, which were largely untouched virgin forest until the first decades of this century, have been merged into one zone.

[a] Prance (1) presents some current ideas on the subject of refugia. See especially, chapter 31 on South-East Asia.

[b] See Wang, Chi-Wu (1), pp. 19–24, for a review of studies of the natural vegetation of China.

[c] *Ibid.*, p. 10.

[d] Hou Hsüeh-Yü *et al.* (1). See Figure 116.

[e] Wên (1), pp. 18–22.

[1] 侯學煜 [2] 文煥然 [3] 興安嶺

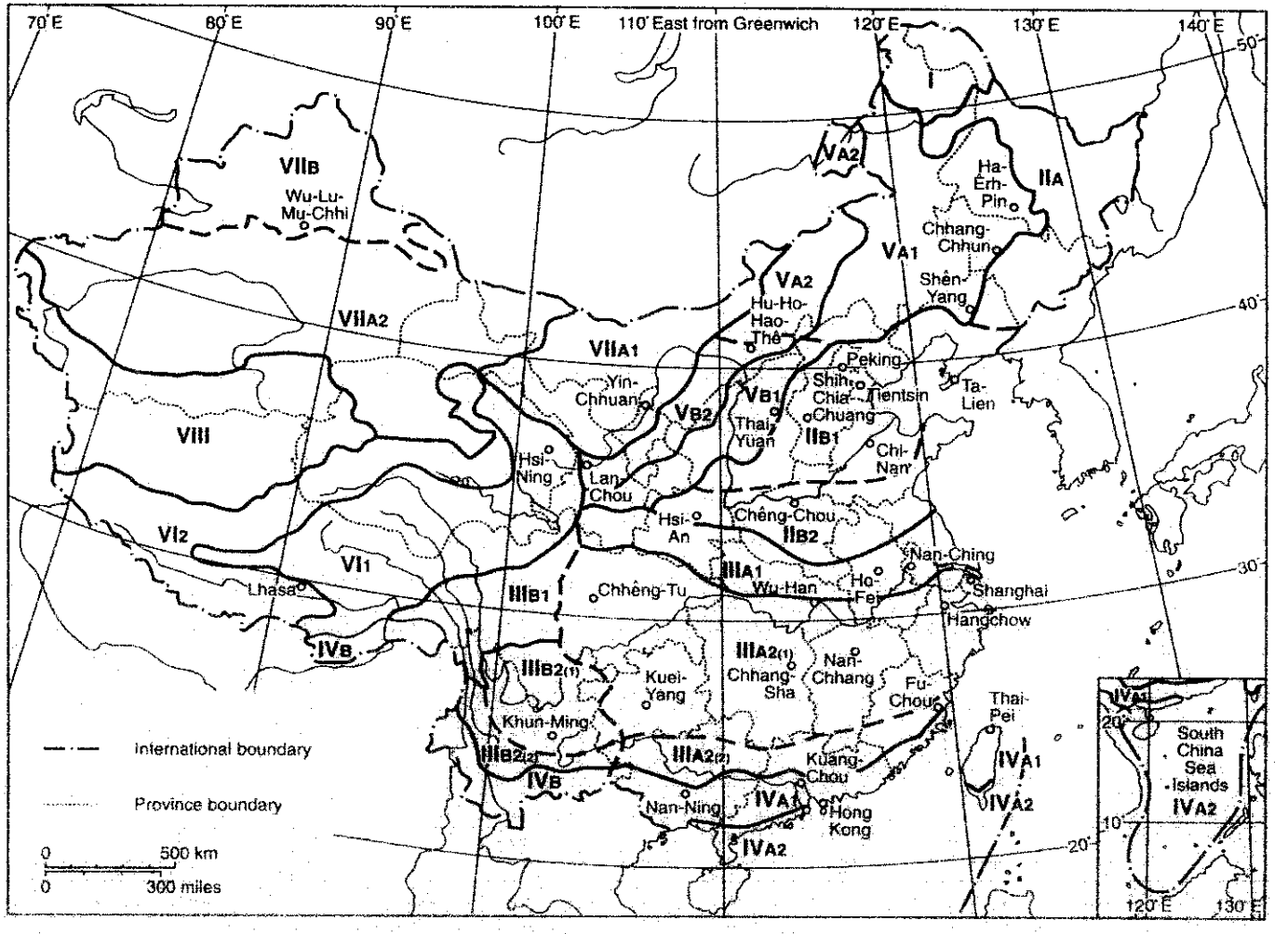
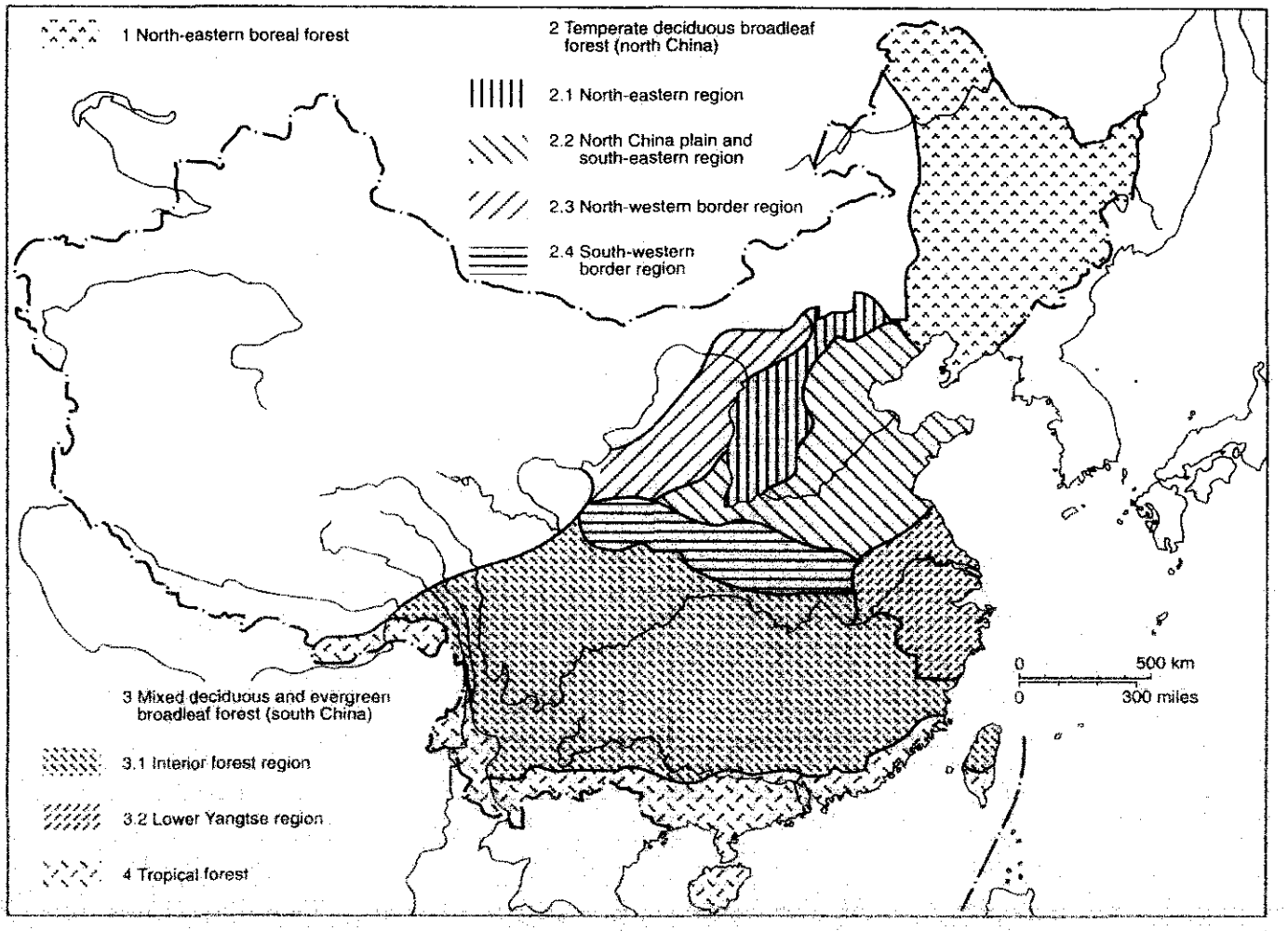


Fig. 116. Map of the vegetation zones of China; after map in Hou Hsüeh-Yü *et al.* (1). For a key to this map see Table 20.

Table 20. *The vegetation zones of China*

I	Boreal deciduous and evergreen forest zone
II	Temperate deciduous broadleaf forest zone
	IIA Sub-zone of deciduous broadleaf forest with some conifers
	IIB Sub-zone of deciduous broadleaf forest with some conifers.
	IIB1 Region of deciduous broadleaf forest
	IIB2 Region of deciduous broadleaf forest with some subtropical deciduous species
III	Subtropical evergreen broadleaf forest zone
	IIIA Eastern sub-zone, evergreen broadleaf forest.
	IIIA1 Region of deciduous forest with some evergreen broadleaf species
	IIIA2 Region of evergreen broadleaf forest
	IIIA2(1) Sub-region of evergreen broadleaf forest
	IIIA2(2) Sub-region of evergreen broadleaf forest with some tropical species
	IIIB Western sub-zone, evergreen broadleaf forest
	IIIB1 Region of sclerophyllous evergreen broadleaf forest
	IIIB2 Region of evergreen broadleaf forest.
	IIIB2(1) Sub-region of evergreen broadleaf forest.
	IIIB2(2) Sub-region of evergreen broadleaf forest with some tropical species
IV	Tropical monsoon forest zone
	IVA Eastern sub-zone, tropical monsoon forest
	IVA1 Region of monsoon-type evergreen broadleaf forest
	IVA2 Region of monsoon forest
	IVB Western sub-zone, tropical monsoon forest
V	Temperate grassland zone
	VA Northern sub-zone, northern grassland
	VA1 Region of wooded grassland
	VA2 Region of grasslands
	VB Southern sub-zone, grassland
	VB1 Region of wooded grassland
	VB2 Region of grasslands
VI	Altiplano grassland zone
	VI1 Region of wooded pasturelands
	VI2 Region of grasslands
VII	Temperate desert zone
	VIIA Sub-zone of southern desert
	VIIA1 Region of semi-desert and desert
	VIIA2 Region of desert and bare ground
	VIIB Sub-zone of northern desert
VIII	Zone of altiplano semi-desert and desert

From Hou Hsüeh-Yü *et al.* (1).



Map 6. The forest zones of China based on natural vegetation and human utilisation.

Table 21. *The forest zones of China based on natural vegetation and human utilisation*

The species listed in this table are based on the dominant species of the forest communities in Wang Chi-Wu's 'Forests of China' (Wang, Chi-Wu (1)), and on the 'Vegetation Map of the People's Republic of China' (*Chung Hua Jên Min Kung Ho Kuo Chih Pei Thu*[1]), published under the direction of Hou Hsüeh-Yü (Hou Hsüeh-Yü *et al.* (1)). For more detailed listings see either of these two works. The zones listed correspond to those shown in Map 6.

1 NORTH-EASTERN BOREAL FOREST

Hsing An Ling[2] mountains of Hei-Lung-Chiang, Chi-Lin, and Liao-Ning provinces and the north-eastern extension of Inner Mongolia. Also the higher slopes (above 1,600 metres) of the Chhang Pai[3] mountains of Chi-Lin province.

COMPOSITION: Larch, especially *Larix gmelini*, *Larix sibirica*, and Korean pine, *Pinus koraiensis*. On the higher slopes of the Chhang Pai Shan, the most important conifers are spruce, especially *Picea jezoensis*, and *Picea sibirica*. Some true firs such as *Abies holophylla* and *Abies nephrolepis*. Birch *Betula* and poplar, especially the mountain poplar, *Populus davidiana*, are also found on the lower slopes.

2 TEMPERATE DECIDUOUS BROADLEAF FOREST OF NORTH CHINA

2.1 NORTH-EASTERN REGION. The arc of mountains trending south-westward from Liao-Ning. Major mountain ranges are the Yen Shan[4], Wu Thai Shan[5], Lü Liang Shan[6], and Thai Hang Shan[7].

COMPOSITION: The lowlands and low foothills are now almost entirely used for agriculture. Poplars and willows are commonly grown. An association of oak *Quercus mongolica* and hazels *Corylus* Spp. occupies some lower slopes. Other oaks found in relict forests or in small groves are *Quercus liaotungensis*, *Q. dentata*, and *Q. glandulifera*. They are usually interspersed with species such as ash *Fraxinus* Spp., maple *Acer* Spp., and elm *Ulmus* Spp. On drier sites the broadleaf forest may be replaced by the pine, mostly *Pinus tabulaeformis*, and Chinese *arbor vitae*, *Platycladus orientalis*. Coniferous forest similar to the north-eastern spruce and larch forests occurs above 1,600 metres.

2.2 NORTH CHINA PLAIN AND SOUTH-EASTERN REGION. Extends as far south as the Ta Pieh Shan[8], and as far west as the Ta Pa Shan[9].

COMPOSITION: Mostly agricultural now. Remaining forests in mountains and protected areas (such as temples and the sacred peak of Thai Shan[10]) are dominated by deciduous oaks, including *Quercus variabilis*, and associations of oak and ash (*Fraxinus* Spp.). Drier sites may have open forest of oak *Q. dentata*, or pine *Pinus tabulaeformis*.

2.3 NORTH-WESTERN BORDER REGION. Ordos plateau, Ning-Hsia and Kan-Su. This is the ecotone between the Central Asian steppe grasslands and the eastern forests. The arid climate restricts forests to higher elevations.

COMPOSITION: Some mixed birch *Betula* and poplar *Populus* at higher elevations. Lower slopes may only support grass cover, or occasionally scattered pines *Pinus tabulaeformis* and arbor vitae, *Platycladus orientalis*, or elms *Ulmus*, maples *Acer*, and willows *Salix*.

2.4 SOUTH-WESTERN BORDER REGION. The boundary between the drainages of the Yellow River and the Yangtse River. Two major mountain ranges, the Min Shan[11], and the Chhin Ling Shan[12].

(*cont.*)

Table 21 (*cont.*)

COMPOSITION: Mostly oak forest and birch forest similar to the north-eastern region sometimes mixed with southern species such as evergreen oak *Quercus baronii*. Spruce *Picea* Spp., and fir *Abies* Spp. at higher elevations. Some *Pinus tabulaeformis* and *Platycladus orientalis* occasionally with the southern pine *Pinus armandii*.

3 MIXED DECIDUOUS AND EVERGREEN BROADLEAF FOREST OF SOUTHERN CHINA

3.1 INTERIOR FOREST REGION. From the Chhin Ling mountains in the north to the mountains dividing Hu-Nan and Kuang-Hsi provinces in the south. Includes Taiwan, the foothills of the Ta Hsüeh Shan[13] in western Ssu-Chhuan, and the Yunnan highlands.

COMPOSITON: A very diverse region, with most genera represented by many species. Increasing evergreen component towards the south. Many of the same deciduous genera as in the northern forests including *Acer* Spp., *Betula* Spp., *Fraxinus* Spp., *Tilia* Spp., and *Ulmus* Spp. Some genera found only in the southern broadleaf forest are *Carya*, *Firmiana*, *Liquidambar*, and *Sassafras*. Twelve genera of conifers have been described mixed in with the hardwoods. Some scattered populations of the 'living fossils', *Ginkgo*, *Metasequoia*, and *Taiwania*. Hemlock *Tsuga* Spp., at higher elevations. *Schima*, *Castanopsis*, and *Quercus* are the main evergreens. Members of the laurel family become important in the south, especially camphor *Cinnamonum camphora*, *Cassia* Spp., and the valuable timber species, *Phoebe nanmu*. The southernmost areas of the region are evergreen oak–laurel forests, believed to represent a centre of speciation of these families. Bamboo, Masson's pine *Pinus massoniana*, and *Cunninghamia lanceolata* (sometimes inaccurately referred to as 'China Fir') are grown in plantations throughout this region. Coniferous forests on montane slopes support coniferous forests of pines *Pinus* Spp., hemlock *Tsuga* Spp., spruce *Picea* Spp., and fir *Abies* Spp.

3.2 LOWER YANGTSE REGION, YANGTSE ESTUARY. Chekiang, Chiang-Hsi and northern Fukien provinces. Ssu Ming Shan[14], Chiu Hua Shan[15], and Thien Mu Shan[16] mountains.

COMPOSITION: A region characterised by many endemics. A high diversity of species with no dominant trees. Wang Chi-Wu lists 180 species of trees which have been identified in the Thien Mu Shan alone. Mostly the same deciduous genera as in the interior region. Some evergreen oaks *Quercus* Spp., *Magnolia* Spp., camphor *Cinnamonum camphora* and other evergreens. Conifers include *Cryptomeria*, with cultivated stands of cypress *Cupressus funebris* and Masson's pine *Pinus massoniana*. Possibly some wild populations of *Ginkgo biloba*.

4 THE TROPICAL FORESTS OF SOUTH CHINA

Hainan Island, southern Taiwan. Kuang-Tung, Kuang-Hsi, and Yunnan provinces, south of the Red River watershed.

COMPOSITION: The oak–laurel association of the southern interior forest region is found at higher elevations. Rain forest on lower slopes and valley bottoms is similar in composition to rain forests elsewhere in continental Asia and Australasia. Over 60 genera of trees have been recorded.[a] Coastal forests of mangrove *Rhizophora mucronata* in some areas.

[a] See Wang, Chi-Wu (1), p. 161, for a list of the most important genera.

[1] 中華人民共和國植被圖
[2] 興安嶺
[3] 長白
[4] 燕山
[5] 五臺山
[6] 呂梁山
[7] 太行山
[8] 大別山
[9] 大巴山
[10] 泰山
[11] 岷山
[12] 秦嶺山
[13] 大雪山
[14] 四明山
[15] 九華山
[16] 天目山

The four forest zones used here in describing changes in forest cover are the north-eastern boreal forest, the temperate deciduous broadleaf forest of north China, the mixed deciduous and evergreen broadleaf forest of southern China, and the tropical forests of south China. These zones are subdivided into regions on the basis of the history of human settlement and topography. Mountain ranges have been used to define the regions because the distribution and composition of forests vary with altitude, and mountains have affected historical patterns of forest utilisation by acting as barriers (or sometimes as channels) to human settlement.[a]

(ii) *The changing landscape*

In the north-east and the tropical south, the forests remain largely intact and are now the major timber-producing areas of China. Historically both were on the fringes of the country, and although they exported some wood and other forest products, deforestation was not significant until the 20th century. The exploitation of the southern mixed deciduous and evergreen broadleaf forest began with the first settled agricultural communities during the neolithic age, and conversion of forest to agricultural land has altered the landscape significantly. However, much of this region is mountainous and inaccessible, allowing the survival of extensive areas of natural forest. Extrapolating from what is known about these areas, it is possible to conclude that the broadleaf forest covered most of southern China, with some variations in density and composition due to localised environmental conditions such as unusual microclimates, alkaline or waterlogged soils and elevation.

In north China, by contrast, millenia of agriculture have transformed the landscape leaving little evidence of the original vegetation of the loess plateau, the earliest centre of the Chinese State. One opinion is that 'The ancient history of China distinctly indicates the super-abundance of forests in this region before 2000 BC'.[b] At the other extreme are those who argue that the area was never covered by more than sparse brush and steppe-like grassland.[c]

Studies of oracle-bone inscriptions and of animal remains excavated in the Shang capital at An-Yang[1] show that three to four thousand years ago, the climate of north China was probably about 2°C warmer than now, and that precipitation was higher than at present.[d] Debate now centres on the possibility that deforestation may have been the cause of this cooling and dessication of the climate.[e]

In 1907, E. Huntington proposed the theory that climatic change, by which

[a] Table 21 and Map 6 give details of the composition and distribution of these forest zones and regions.
[b] Teng (2), p. 190.
[c] Handel-Mazetti (1), p. 313.
[d] Chu Kho-Chên (11), and Chang Fang (1).
[e] The debate on this subject is summarised in Li Pao-Thien[2] (1).

[1] 安陽 [2] 李寶田

he meant a fall in precipitation, had caused the collapse of Chinese power in Central Asia during the medieval period.[a] W. G. Lowdermilk, on the other hand, believed that deforestation and erosion alone could account for the apparent decline of agricultural productivity in north China.[b] In 1935, V. K. Ting questioned the assumption of a consistent deterioration of the climate of north China, showing that the incidence of floods and famines is not correlated statistically with changes in rainfall.[c]

The influence of forests on climate is still poorly understood. A distinction must first be drawn between localised effects, and regional, or even global, effects. Trees moderate their immediate environment. Deforestation can therefore alter micro-climates and hamper regeneration in harsh climates, a significant factor in north China. The functions of forests in regulating climate on a large scale are not so clear. We know that water is recycled into the atmosphere through evapotranspiration, but research is only beginning to evaluate how far it is carried before it condenses and falls again as rain.[d] It is not yet possible to decide whether climatic change in north China is the result of deforestation, or whether it is related, instead, to worldwide changes in climate.

There is still no conclusive evidence to support the assumption, central to the thesis of dessication, that the loess plateau was originally well forested. Early settlements such as Pan-Pho[1] near Hsi-An[2], Shensi province, were located near the ecotone between the western grasslands and the eastern woodlands. There is no doubt that trees were present at these sites, since excavations show that poles were used in building and wood ash from midden fires has been found. It is also accepted that most of the burden of silt carried by the Yellow River is soil eroded from devegetated hillsides in the loess plateau.[e] The conventional interpretation of these observations is that the whole of this region was originally well forested. Settled agriculture began in the river valleys and gradually spread up the hillsides, exposing the friable loess soils to erosion, starting the cycle of siltation and flooding.[f]

Five main forms of evidence have been used to support this scenario. They are literary records, archaeological excavations, palynology, palaeontology and the study of relict vegetation such as protected temple forests. Caution is needed, though, in using each of these sources. They tell us that there were trees on the north China plain and the loess plateau. They do not tell us

[a] Huntington (1).
[b] Lowdermilk (4), and (1).
[c] Ting (1).
[d] Lockwood (1), ch. 6, is a summary of current knowledge of the role played by forests in regulating climate.
[e] There is geological evidence, though, that there was some siltation in the Yellow River before any human settlement had taken place. See Wang Yung-Chhüan[3] (1).
[f] A number of papers and forest histories written recently in China have followed this interpretation. Cf. Ling Ta-Hsieh[4] (1), Chang Fan[5] (1), and Chang Chün[6] (1).

[1] 半坡 [2] 西安 [3] 王涌泉 [4] 凌大燮 [5] 張帆
[6] 長軍

whether trees dominated the ecosystem, or whether they were just one component in a more complex system including grasses, shrubs and brush. References to trees in the *Book of Odes* (*Shih Ching*[1]) indicate the presence of certain species, so far as they can be identified, but tell us very little about the appearance of the landscape during the Western Chou period (c. −1045 to −771) when most of the poems were composed.[a] It is reading too much into the text to say, for example, that because a poem describes a tree being felled, this indicates that the area was densely forested.

Archaeological evidence shows that wood was used in the neolithic societies, but it is wrong to assume that a densely forested environment is necessary for wood to be used as a building material. Shih Nien-Hai[2] justifies his assumption on the grounds that 'in those rough and pioneering times, communications were still undeveloped, and timber is bulky making it difficult to fetch it from a distance, so it had to be brought from nearby locations.'[b] This might be true for large timber, but the poles used in the construction of huts could be carried to the village from scattered trees a short distance away, and it would be equally plausible to hypothesise a savannah-like landscape with scattered trees in association with shrubs and grassland.

The presence of tree pollen at archaeological sites again confirms the presence of trees, but existing data do not give a very clear idea of their spatial distribution. Caution is needed in using palynological evidence. Settlements are generally located close to a permanent supply of water, where riparian vegetation with more trees would be expected. Cores drilled in the course of recent geological research in the loess plateau, at some distance from known settlements, contain very little tree pollen after the deposition of the loess mantle during the Quaternary.[c]

The available evidence does not warrant the generalisation that the primitive landscape of north China was uniformly forested. Dense jungle, savannah grassland interspersed with trees, and grassland with riparian forest are just three of many possible forms of forest cover. It has been said, for example, that the representation of animals such as the rhinoceros and the tiger in the bronzes of the Shang and Chou periods is confirmation that dense forest covered the area controlled by the early Chinese State. The habitat of the rhinoceros is open woodland and grassland while the tiger requires some dense cover for its lair, but hunts in woodland and grassland.[d] Scrub and brush which may have been im-

[a] Kêng Hsüan[3] has identified most of the common plants and trees in the *Book of Odes*. See Kêng (*1*).

[b] Shih (*1*), p. 234. All translations in the text and footnotes are my own, unless otherwise indicated.

[c] Shensi Geological Research Institute (1), chapter 3, 'Stratigraphy'. Pearson (1), p. 227, adds a further warning that loess soil is 'a notably poor environment for the preservation of pollen grains' and that the shrubby genus *Artemisia* may be over represented in samples because its pollen survives better than most arboreal pollens.

[d] The gazetteer of Lin Hsien[4], Ho-Nan province, reported in 1752 that the county had no forest, but it also said that there were problems with tigers in the mountains. +1752 *Lin Hsien Chih*[5], ch. 5, p. 19b.

[1] 詩經 [2] 史念海 [3] 耿煊 [4] 林縣 [5] 林縣志

portant components of the vegetation provide suitable habitat for both these species.

A careful reading of the literary sources suggests that the vegetation cover of the north China plain and the loess plateau was not uniform. The economic reforms proposed for the State of Chhin[1] by Shang Yang[2] (d. −338), included a section concerning land-use planning. If these reforms had been fully implemented, both forest and grassland would have been recognised as categories distinct from agricultural land,[a] which suggests that both vegetation types were significant features of the landscape at the time. Poems in the *Book of Odes* distinguish between the trees which grow close to rivers, and the trees on higher ground.[b] At still higher elevations, conifers are usually referred to as being found in the mountains.[c]

The availability of water is the most important factor determining the distribution of vegetation in the semi-arid climate of north China. Sites subject to water stress, such as south-facing slopes or rocky ridgetops, support sparser forest than the cooler, more mesic sites. A recent survey showed a distinct difference in the distribution of species and density of forest cover on north- and south-facing slopes in the mountains outside Peking.[d] To the west, where the climate is drier, the importance of aspect is even more apparent, with grassland on south-facing slopes, and woodland on the north-facing slopes (Fig. 117).

The picture of the original landscape of north China which emerges from these observations is neither of dense forest nor of a barren steppe, but rather of a mosaic of vegetation. There was fairly thick forest around rivers and other permanent sources of water. The plains were probably covered in rather sparse deciduous woodland, opening out to savannah grasslands with scattered trees or brush in the northwest, in what is now northern Shensi province, and most of the Ordos plateau of Inner Mongolia. Denser deciduous woodland was found on the foothills of the mountains, with scrub and brush or drought-tolerant species on south-facing slopes. Coniferous forests dominated the higher elevations above about 1,500 metres with larch and spruce forming the highest forests just below timberline.

(3) Vegetation Changes: the Pattern of Deforestation

Tracing the progress of deforestation requires searching through historical and literary sources for any mention of forests, of scarcity of timber, or for informa-

[a] *Shang Chün Shu*[3], ch. 4, *Lai Min*[4], p. 27.

[b] Cf. *Thang Fêng*[5], *Shan Yu Shu*[6], Karlgren (14) no. 115, p. 74. Also *Chhin Fêng*[7], *Chü Lin*[8], Karlgren (14) no. 126, p. 80.

[c] This is particularly noticeable in the descriptions of mountains in the *Shan Hai Ching*.

[d] Lin Chhao[9] & Li Chhang-Wên[10] (*1*), p. 22.

[1] 秦 [2] 商鞅 [3] 商君書 [4] 徠民 [5] 唐風
[6] 山有樞 [7] 秦風 [8] 車鄰 [9] 林超 [10] 李昌文



Fig. 117. Vegetation distribution. *Picea asperata* forest in Kan-Su; from Wang Chi-Wu (1), opposite p. 62.

tion on land use. Shih Nien-Hai[1] has carried out the most detailed survey of this kind in his work on the geography of the middle Yellow River region.[a] A regional study has also been made by Chhên Chhiao-I[2] of the area of the Yangtse estuary, with particular reference to the Hui Chi[3] mountains of Chekiang province.[b] Wên Huan-Jan[4] has published one of the few serious attempts to date to follow the changes in forest cover over the whole of China, relating periods of forest destruction to factors such as periods of war and rebellion, internal migration, and changes in agricultural technology.[c] These three sources have been essential references in preparing this outline of changes in the forest cover of China.

(i) *Northeastern and northern China*

The earliest archaeological sites in the northeastern boreal forests have been dated to the period between −1000 and −2000. Ashes and birch bark found at these sites indicate that hunters and gatherers used the resources of the for-

[a] Shih (*1*), pp. 232–313, Shih (*2*).
[b] Chhên Chhiao-I (*3*).
[c] Wên (*1*).

[1] 史念海 [2] 陳橋驛 [3] 會稽(山) [4] 文煥然

est, although they could not have significantly reduced its extent.[a] The first evidence of settled agricultural societies dates from about +300,[b] but it seems that most of the northeast was home to nomadic and pastoral tribes throughout the historical period, until the +18th century or later. During the +13th century, the dominant group in the area was the Nü Chên[1] who were described as 'having no markets, wells, city walls or fortifications, they live wherever they find water and pasture, their main occupation is hunting'.[c] The Manchus themselves were originally a nomadic people. After establishing the Chhing dynasty in +1644, they attempted to enforce a ban on settlement in their homeland, which although it was only partly successful, did succeed in protecting large areas of forest until the early 20th century.[d]

The site of the Shang capital at An-Yang[2] is located at the foot of the Thai Hang[3] mountains, in the northeastern region of the temperate deciduous broadleaf forest. Much of the original vegetation still remained during the Shang period (traditionally said to have lasted from c. −1520 to c. −1030) since inscriptions on oracle bones indicate that slash-and-burn techniques were commonly used to open up new land for agriculture.[e] Other oracle bones record that large numbers of animals were captured or killed on hunting expeditions, confirming that habitat for wildlife, be it forest, scrub or grassland, was still widespread.[f]

This region did not suffer shortages of wood until the medieval period. Enough fuelwood was available during the +2nd century for iron to be produced, and porcelain kilns which also require a ready supply of energy have been excavated here.[g] Temple inscriptions and descriptions of the landscape recorded by the compilers of different editions of the gazetteer of Lin Hsien[4] show that vegetation cover in the county was constantly changing over time. According to a temple inscription in Lin Hsien dating from the early Sung (+988), officials were appointed to procure wood from all parts of Ho-Pei for military supplies.[h] Less than two centuries later, the situation had changed. Deforestation in the Thai Hang mountains prompted Shên Kua[5] to write that 'it has gradually reached the stage that in the Thai Hang mountains ... at least half the slopes have been denuded of pines.'[i]

Depopulation following the warfare of the mid +17th century and the col-

[a] Hei-Lung-Chiang Shêng Po Wu Kuan (2), and Ning-An Hsien Wên Wu Kuan Li So (1). We should not assume that hunter gatherers are incapable of modifying the structure and composition of the forest. The American Indians consciously manipulated the forest to improve wildlife habitat and to favour the growth of certain desired species. See Cronon (1), chapters 2 and 3.

[b] Hei-Lung-Chiang Shêng Po Wu Kuan (3).

[c] *Yüan Shih*, ch. 59, *Ti Li Chih*[6] (2), p. 1400.

[d] Wu Chhuan-Chün[7] (1).

[e] Hu Hou-Hsüan[8] (1).

[f] Chang (5), pp. 142–3.

[g] Pei-Ching Kang Thieh Hsüeh Yüan ... (1), and Ho-Pei Shêng Wên Wu Kuan Li Chhu (1).

[h] 1932 *Lin Hsien Chih*, ch. 14, p. 10a.

[i] *Mêng Chhi Pi Than*[9], ch. 24, p. 745, no. 421.

[1] 女貞 [2] 安陽 [3] 太行 [4] 林縣 [5] 沈括
[6] 地理志 [7] 吳傳鈞 [8] 胡厚宣 [9] 夢溪筆談

lapse of the Ming dynasty may have relieved the pressures on the forest to some extent. Wên Huan-Jan notes that there are many references in a Khang Hsi edition of the gazetteer of Lin Hsien to abandoned fields reverting to brush.[a] Such periods of recovery were short-lived. Fifty years later, fruit trees were grown on the hillsides as cash crops, but timber was in such short supply that the inhabitants were forced to resort to some unconventional building technology:

They take what is inexhaustible and can never be used up. They only use rocks from the mountains, always building their houses with the mountainside forming one wall, with no partition walls or supporting pillars,... they plait thorn bushes to make posts for their homes, and weave sorghum stalks for mats.[b]

The flatter lands of the north China plain were the site of early societies such as the Yang-Shao[1] culture (c. −6000) which practised agriculture. Deforestation was already noticeable by the −5th century, when Mencius referred to the 'bare and stripped appearance' of Ox Mountain (Niu Shan[2]) in the state of Chhi[3], in modern Shan-Tung.[c] Some parts of north China still had adequate forest cover during the Han dynasty. State intervention was needed, though, to ensure a regular supply of wood to cities where serious shortages were being experienced. The *Yen Thieh Lun*[4], 'Discourses on Salt and Iron' records, probably a few decades after the event, the heated debate about the role of the State in administering the production and distribution of natural resources which took place in the year −81. References to the problem of timber supply give a vivid picture of the uneven extent of forests by this time:[d]

Now the supply of bamboo in Wu[5] and Yüeh[6], and the timber in Sui[7] and Thang[8] is more than can be used while in Tshao[9], Wei[10], Liang[11] and Sung[12] they are forced to use coffins over again for the dead.

The dynastic histories often mention that large sizes of timber for the construction and reconstruction of the capital had to be brought from remote mountain areas at great expense, occasionally prompting warnings from officials that the people were being forced to the brink of rebellion.[e] By the *Khai-Yüan*[13] period of the Thang dynasty (+713 to +741), timber had to be procured

[a] Wen (*1*), p. 27.
[b] +1752 *Lin Hsien Chih*, ch. 5, pp. 10b–11a.
[c] *Mêng Tzu, Liang Hui Wang, shang*[14] VI, i, 8. Transl., Legge (3), p. 407.
[d] *Yen Thieh Lun*, ch. 1.3, *Thung Yu*[15], p. 9b, transl., Gale (1), p. 20. Wu and Yüeh were southern States in the Yangtse basin. Sui and Thang were to the southeast of Lo-Yang, in modern Hu-Pei province. Tshao, Wei, Liang and Sung were to the east and northeast of the capital in modern Shan-Tung, Shan-Hsi, and Ho-Nan provinces.
[e] *Chou Shu*[16], ch. 18, *Wang Phi Chuan*[17], p. 291.

[1] 仰韶 [2] 牛山 [3] 齊 [4] 鹽鐵論 [5] 吳
[6] 越 [7] 隋 [8] 唐 [9] 曹 [10] 魏
[11] 梁 [12] 宋 [13] 開元 [14] 梁惠王上 [15] 通游
[16] 周書 [17] 王熊傳

from as far away as Shêng[1] in modern Inner Mongolia.[a] The population of this region fluctuated during the whole of the medieval period, due to warfare and rebellion. There may have been periods in which depopulation allowed some recovery of the vegetation, but the overall picture of timber scarcity persists to the present.

The northwestern borderlands represented a shifting boundary between the settled agriculture practised by the Han Chinese and the nomadic pastoralism of the Central Asian tribes. The boundary moved with the changes in political power between the two groups, and Shih Nien-Hai[2] has pointed out that the locations of different branches of the Great Wall give a fairly accurate picture of the boundary between agriculture and pastoralism.[b]

The Chhin-Ling range, stretching from east to west, divides the temperate deciduous broadleaf forest of north China from the mixed deciduous and evergreen broadleaf forest of south China. The extravagant use of timber from these mountains by the first Chhin Emperor (Chhin Shih Huang[3]) to build his A-Phang Palace (*A-Phang Kung*[4]) was remembered a thousand years later in these lines by the Thang poet Tu Mu[5]:

> The six sovereigns were destroyed,
> The four seas united,
> The mountains of Shu destroyed,
> Before A-Phang was built.[c]

These mountains have never been densely populated, so the pattern of forest exploitation has been episodic rather than a continuing conversion of the land to agricultural use. The difficulty of the terrain made the extraction of timber a costly operation, which was only viable at times of exceptional demand. In +1132, a new palace was built at Khai-Fêng[6] for the Chin Emperor. Timber was brought to the capital from the Chhing Fêng[7] mountains, 'which had been inaccessible since the Thang and the Sung dynasties.'[d] A more recent episode of exploitation took place during the +18th century, a period of steady economic growth. Large-scale logging operations in the border region of Shensi, Ssu-Chhuan, and Hu-Pei employed several tens of thousands of men supplying fuel to iron foundries in the mountains, and timber to the cities in the lowlands.[e]

[a] *Hsin Thang Shu*[8], ch. 167, *Phei Yen-Ling Chuan*[9], p. 5108.
[b] Shih Nien-Hai (*1*), p. 24. See Lattimore (1) on the importance of the Inner Asian frontier. Also, Kiseleva (1) for an attempt to reconstruct the original vegetation of the Mongolian plateau.
[c] Tu Mu, *A-Phang Kung Fu*[10], in *Fan Chhuan Wên Chi*[11], ch. 1, p. 1a.
[d] *Chin Shih*[12], ch. 79, *Chang Chung-Yen Chuan*[13], p. 1789.
[e] Yen Ju-Yü[14] (*2*), *San Shêng Pien Fang Pei Lan*[15], ch. 9.

[1] 勝 [2] 史念海 [3] 秦始皇 [4] 阿房宮 [5] 杜牧
[6] 開封 [7] 青峰山 [8] 新唐書 [9] 裴延齡傳 [10] 阿房宮賦
[11] 樊川文集 [12] 金史 [13] 張中彥傳 [14] 嚴如煜 [15] 三省邊防備覽

(ii) *South China*

Archaeological excavations at Ho-Mu-Tu[1] near Shao-Hsing[2] show that agriculture was practised there as early as −5000, demonstrating that the Yangtse basin was settled at about the same time as the loess plateau. This area was culturally distinct from the Shang and Chou States of north China, but was known by them as a supplier of timber. It appears under the name Yang-Chou[3] in the 'Tribute of Yü' (*Yü Kung*[4]) which says 'it has grasslands, its trees are tall and stately'.[a] Scattered references indicate that the region was well forested at least until the +1st century. In 487, King Kou Chien[5] of the State of Yüeh[6] sent 'more than three thousand people into the forests to cut timber for more than a year'[b] in order to build a navy. In −472, the same king moved his capital and sent 'two thousand eight hundred men to cut pines and cypress and make them up into rafts [to transport the logs]'.[c] The 'Discourses on Salt and Iron' (*Yen Thieh Lun*) still referred to Wu and Yüeh as States with an abundance of timber, in contrast to some of the northern States.

In the year +353, a gathering of poets was held at Lan Thing[7] in the foothills of the Hui Chi[8] mountains. Chhên Chhiao-I has concluded from a study of the descriptive poems written for the occasion that, by this time, the flat lands of the Yangtse estuary were cultivated, but that the hills and mountains were still covered by forests.[d] The *Chha Ching*[9], 'Classic on Tea', a Thang dynasty work by Lu Yü[10] praises the tea from Yüeh indicating that by the +8th century, forest had been cleared at least from the foothills to make way for tea plantations. The flight of the Sung court from Khai-Fêng to Hangchow in +1127 was accompanied by a major migration of the population from north to south imposing further pressures on the nearby forests. A +13th-century treatise on hydraulic engineering in the Yangtse estuary places the blame for siltation on the recent deforestation of even the more remote mountains.[e]

As long as rice or millet were the only staple crops available, some forest remained where steep slopes and difficult access made their cultivation impossible. The introduction of maize and sweet potatoes during the +16th and

[a] *Shu Ching, Hsia Shu, Yü Kung*, Legge (1), p. 108.

[b] *Wu Yüeh Chhun Chhiu*[11] (a romantic rather than a factual account of the wars between Wu and Yüeh in the −5th century), ch. 5.9, p. 183. For a history of the State of Yüeh, see Chhên Chhiao-I[12] (2).

[c] *Yüeh Chüeh Shu*[13] (essays on matters arising from the wars of Wu and Yüeh), ch. 9, p. 43. The word I have translated as 'cypress' is *po*, which actually refers to several different species related to the cypress. See (*b*) (2), below on *po*.

[d] Chhên Chhiao-I (*1*), p. 132. The gathering of poets is described in the *Chin Shu*[14], ch. 50.

[e] *Ssu Ming Tho Shan Shui Li Pei Lan*[15], ch. 1, p. 6b. Transl. on p. 653 below.

[1] 河姆渡 [2] 紹興 [3] 揚州 [4] 禹貢 [5] 勾踐
[6] 越 [7] 蘭亭 [8] 會稽(山) [9] 茶經 [10] 陸羽
[11] 吳越春秋 [12] 陳橋驛 [13] 越絕書 [14] 晉書
[15] 四明它山水利備覽

+17th centuries opened up even these areas to cultivation.[a] Deforestation caused serious erosion and disruption of stream flows. Attempts were made to prohibit forest clearance,[b] but they were ineffective. Officials could do no more than lament the damage caused by hill farming, as in this passage from the Gazetteer of Hsüan Phing county[1], Chekiang province:[c]

When it (maize) is planted in the mountains, the soil is loosened and rocks emerge. Whenever there is a rainstorm, the rocks slide down the slopes, following the lie of the land. Silt and sand-bars block the flow [of streams]. This is the reason that since the floods of Chia Chhing 5 (−1801), there has been a catastrophic accumulation of sand and rocks in streams and pools, and water cannot accumulate . . .

The forests of the interior region of south China were not significantly affected by early settlement. The 'Geographical Treatise' in the +1st century *Han Shu*[2] said of the state of Chhu[3], modern Hu-Nan, that 'there is abundant land which is either ploughed after burning, or flooded and cultivated.[d] The people eat fish and rice, living by fishing, hunting and cutting timber in the mountains.'[e]

During the period of disunity which followed the collapse of the Han dynasty (c. +220 to +265), the three warring kingdoms fought some major battles in the upper Yangtse basin and in the flatter country surrounding Tung Thing[4] lake where the Hsiang[5] river enters the Yangtse. A common strategy was to burn the forests to flush out rival armies.[f] Records of floods and the changing level of Tung Thing Lake due to siltation indicate severe deforestation at this time.[g] Thang poems suggest that by the +8th and +9th centuries, natural regeneration had restored the forest cover, but by the +12th century, siltation had raised the level of the lake bed again, causing renewed flooding.[h]

The pattern of deforestation in this interior region after the transfer of the Sung capital to Hangchow, is similar to the sequence of events in the lower Yangtse region. There were, however, inaccessible areas where untouched forest remained until quite recently. In +1406, when the Ming Emperor Yung Lo rebuilt the palaces in Peking, some of the largest timbers were cut in the mountains of Kuei-Chou and southeastern Hu-Nan,[i] and Kuei-Chou continued to

[a] See Ho, Ping-ti (1), and Vol. 6, pt 2, p. 458 on the introduction of New World crops to China.
[b] See the edict dated +1786 from the gazetteer of Fêng Hua county (*Fêng Hua Hsien Chih*[6]) in Chhên Chhiao-I (*3*), p. 216.
[c] 1878 *Hsüan Phing Hsien Chih*[7], ch. 17. Quoted in Chhên Chhiao-I (*3*), p. 216.
[d] *Nou*[8]. Apparently a reference to wet rice cultivation. See Vol. 6, pt 2, pp. 495–510, on rice cultivation.
[e] *Han Shu, Ti Li Chih*[9], ch. 28, p. 1644.
[f] *San Kuo Chih*[10], *Wu Shu*[11] ch. 58, *Lu Sun chuan*[12], pp. 1346–7. Also ch. 48, *Sun Hao chuan*[13], p. 1167.
[g] Ho Yeh-Hêng[14] & Pien Hung-Hsiang[15] (*1*), p. 465.
[h] *Ibid.*, p. 465.
[i] *Ming Shih*[16], ch. 150, *Shih Khuei chuan*[17], p. 4162.

[1] 宣平縣 [2] 漢書 [3] 楚 [4] 洞庭(湖) [5] 湘
[6] 奉化縣志 [7] 宣平縣志 [8] 耨 [9] 地理志 [10] 三國志
[11] 吳書 [12] 陸孫傳 [13] 孫皓傳 [14] 何業恒 [15] 卞鴻翔
[16] 明史 [17] 師逵傳

supply construction materials into the +18th century.[a] It is important to note, too, that this period of increasing demand for timber is the period in which we begin to find accounts of plantations of cunninghamia (*sha mu*) being grown in mountain valleys where agricultural crops could not be grown. By the +16th century, complex silvicultural systems had evolved to produce cunninghamia in association with food crops and some valuable perennials such as tung oil and tea oil.[b]

The forests of China's tropical south were known throughout the historical period as a benighted land of exile, where pestilential vapours and malaria constantly threatened the health of immigrants. Some tropical woods were used to make furniture, and others were valued for their medicinal qualities.[c] Dalbergia was described, for example, by the Thang botanist, Chhên Tsang-Chhi[1]:[d]

> It comes from Annam and Nan Hai. It is used to make beds and tables. It resembles the purple sandalwoods, but is red, and hard.

The problems and the high costs of shipping and then of transporting these woods overland to urban markets limited the exploitation of the tropical forest until very recently. Following developments in agricultural technology and medicine during the last century, there has been an increase in settlement and conversion of forest to agricultural land. After centuries of *de facto* protection, the threat of deforestation has now reached even the tropical forests of China.

(*b*) TAXONOMY AND IDENTIFICATION OF MAJOR FORESTRY SPECIES

Forestry, agriculture and pomology are patterns of land utilisation located on a spectrum of systems adapted to specific ecological and demographic conditions. To study one of these patterns it is necessary to create artificial boundaries simply to define the object of the investigation. I have chosen in the case of forestry to restrict discussion to species grown primarily for wood products, usually timber or fuelwood. This classification of forest species corresponds fairly closely to the 'Trees and Timber' (*Mu Lei*)[2] sections of botanical works such as the *Chhün Fang Phu*[3] or the *Chih Wu Ming Shih Thu Khao*[4] (Wu Chhi-Chün (*1*)).[e]

The student of forest dendrology in China is faced with a bewildering variety of genera and species, many of which are endemic. The task of identifying species mentioned in classical works is made more complex when the sources are written by scholar officials based in the cities.[f] Indeed, there are problems

[a] *Tsun-I Fu Chih*, ch. 28.
[b] See 'Cunninghamia', (*b*) (3) and 'Cunninghamia and intercropping', (*c*) (4) (ii) below.
[c] See Schafer (16), pp. 171–3, on the trees of tropical south China.
[d] In *PTKM*, ch. 35, p. 2048.
[e] See Vol. 6, pt. 1 for a discussion of these botanical treatises.
[f] See Vol. 6, pt 1, pp. 142–82, on Chinese taxonomy and nomenclature.

[1] 陳藏器 [2] 木類 [3] 群芳譜 [4] 植物名實圖考

with taxonomic nomenclature in the present internationally accepted Linnaean system, not to mention the botanical inaccuracy of many common names.

Categorisation and classification of natural phenomena are subjective operations of the human mind. The categories into which the natural world is divided are not predetermined universals, they are defined by the experiences and perceptions of those who live and work in a particular environment or ecosystem. Lévi-Strauss describes this process in his study of the origins of totemism among tribal peoples, *The Savage Mind*:[a]

> There is a balance between the point of view of extension and that of comprehension in the notion of a species: considered in isolation, a species is a collection of individuals; in relation to other species, however, it is a system of definitions . . . The notion of species thus posesses an internal dynamic: being a collection poised between two systems, the species is the operator which allows (and even makes obligatory) the passage from the unity of a multiplicity to the diversity of a unity.

The earliest descriptions of vegetation available to us are to be found in literary works such as the *Book of Odes*, the *Êrh Ya*[1] and the *Shan Hai Ching*[2].[b] The most common technique used in botanical description was to compare the unfamiliar species to one which was presumably well known to the reader. While this may cause problems for a contemporary reader, or to one from another geographical region, it has the unexpected advantage to the ecological historian of providing information on which species were common at the time of writing. Among the conifers, for example, the *Êrh Ya* describes the juniper (*kuei*[3]) as having the stem of a pine and the foliage of the cypress.[c] Hardwood species frequently used as descriptors in the *Shan Hai Ching* include the elm, *yü*[4] (*Ulmus* spp.), the poplar, *yang*[5] (*Populus* spp.), and the *huai*[6] (*Sophora japonica* L.). Comparisons were drawn between whole trees, or, when more detail was required, specific parts of the tree would be described. Leaf shape, still the most commonly used part of the tree in modern dendrology, is often listed as a distinguishing feature, as are the flowers when readily visible. Other characteristics referred to are the shape of the stem, the bark, the shape of the roots and the growth form of the plant. A typical description from the *Shan Hai Ching* reads:[d]

> There is a tree there with round leaves and a white calyx. It has red flowers with black venation, and a fruit like the *chih*[7] [which the *Shuo Wên* says is like a tangerine].

The following section examines the pines, cypress and juniper, cunninghamia and ginkgo, which were the softwoods most widely used in forestry. The ginkgo

[a] Lévi-Strauss (1), p. 165. Transl., 1966, p. 136.

[b] Oracle-bone inscriptions often mention trees and other plants. See Keightley (2) on the use of oracle-bone records in reconstructing the setting of the early Shang State.

[c] *Êrh Ya, Shih Mu*[8], p. 105. For a discussion on the species translated here as 'cypress', see (*b*) (2), below.

[d] *Shan Hai Ching*, 2, *Hsi Shan Ching*[9], p. 38.

[1] 爾雅 [2] 山海經 [3] 檜 [4] 榆 [5] 楊
[6] 槐 [7] 枳 [8] 釋木 [9] 西山經

is strictly speaking an ornamental, rather than a species grown for timber. It has been grown for many centuries, especially in south China for its beautiful form and foliage, as well as for its fruit, considered to be a delicacy. It seems appropriate to include ginkgo, since it is likely that this unique tree would now be extinct if it had not been cultivated. For the identification of species not examined in detail here, the reader may refer to Bretschneider,[a] Chhên Jung[1],[b] or to the table at the end of the 1981 digest of the *Shou Shih Thung Khao*[2].[c]

(1) Gymnosperms (Conifers and Ginkgo)

(i) *Sung: the pines*

I gaze at the distant pines on the mountain,
However harsh the winter they can never wither.
I think I will break my journeying to rest
And look in awe on their immeasurable perfection.

[Hsieh Shih[3], wife of Wang Ning-Chih[4] (Thang dynasty)][d]

The pines occupy an honoured position among the Chinese literati (Fig. 118). They have been used by both painters and poets to symbolise resilience in adversity while the Chinese scholar owes a direct debt to the pines which provided the soot used as the raw material in the production of ink sticks.[e] The shade and shelter they offer in the mountains made them a symbol of hospitality, and visitors to China today are still greeted in hotels and waiting rooms by large paintings of the 'Pine of Hospitality' *ying kho sung*[5].[f]

Distribution and taxonomy

Pines are found from the edge of the boreal forests of the northern hemisphere to highland areas of the tropics. They are well adapted to harsh edaphic and climatic conditions, and so are often found where other tree species will not survive. This may be a reason why they have become an important timber tree, surviving and even thriving where other more intensive forms of land use are not viable. Chinese writers were quick to notice that the pines are mainly to be found on hills and mountains. The brief descriptions of mountains and rivers in the *Shan Hai Ching* may be of dubious geographical value, but they show that

[a] Bretschneider (1).
[b] Chhên Jung (2).
[c] I Chhin-Hêng[6] (1).
[d] Quoted in *CFPT*, ch. 14, p. 1125.
[e] See Vol. 5, pt 1, pp. 233–51, on ink making in China. The process of making ink from pine soot is illustrated in Fig. 135, p. 657
[f] The 'Pine of Hospitality' is said to be a tree on Huang Shan[7], the scenic mountain in An-Hui province. This would be Masson's pine, *Pinus massoniana*.

[1] 陳嶸 [2] 授時通考 [3] 謝氏 [4] 王凝之 [5] 迎客松
[6] 伊欽恒 [7] 黃山



Fig. 118. Pine trees tenaciously withstanding the elements on a mountain top. One of the most persistent and evocative images of trees in Chinese literature and art. *Pinus armandii* at Chang Chia Chieh Forest National Park, Hu-Nan province; orig. photo N. K. Menzies.

the author or authors already had some perception of the adaptation of vegetation types to their environment. Pines are frequently said to be 'at the top of the mountain', with other trees or grasses growing elsewhere:[a]

[a] *Shan Hai Ching*, 3, *Pei Hai Ching*[1], p. 75. *Hu* is unidentified. The pseudo Khung An-Kuo[2] commentary to the *Shu Ching* says it is used to make arrows. *Shu Ching*[3], *Yü Kung*[4], p. 112, under Ching Chou[5].

The *Shan Hai Ching*, whose various parts may be dated between the Warring States and the Han periods, provides geographical detail together with notes of the flora, fauna and hybrid creatures believed to be present at different sites up and down China, which were seen as the home of mythical creatures or divine spirits. The text partakes of both factual information and fantasy.

[1] 北海經 [2] 孔安國 [3] 書經 [4] 禹貢 [5] 荊州

Two hundred *li* further to the north, is the mountain called Phan Hou[1]. There are many pines and juniper (*po*[2]) at the top, and hazels (*chên*[3]) and *hu*[4] trees below. Jade is abundant to the south, iron is abundant to the north.

Species of pine found in China include some of the most easterly populations of the Scots pine (*P. sylvestris* L. *var. mongolica* Li), found in northeastern China and in Inner Mongolia where it is known as *chang tzu sung*[5]. The major timber species in Liao-Ning, Chi-Lin and Hei-Lung-Chiang provinces in the northeast is Korean pine, *hung sung*[6] (*P. koraiensis* Sieb. et Zucc.). In temples in north China it is common to see fine old specimens of the the very beautiful white-barked pine, *pai phi sung*[7] (*P. bungeana* Zucc.) and of the *yu sung*[8] (*P. tabulaeformis* Carr.), which is the most widely planted species in the northern provinces. In the south, Masson's pine, *ma wei sung*[9] (*P. massoniana* Lamb.) is the main timber species.

The number of needles in a fascicle is often the first attribute used in identifying pines, and we find here a curious discrepancy between the descriptions in the various sources of botanical information. The *Chhün Fang Phu* (c. +1621), for example, says that pines have either three or seven needles.[a] Li Shih-Chên[10] quotes the +11th-century *Pên Tshao Thu Ching*[11] by Su Sung[12] as saying that they have two, five or seven needles. It is odd that while Li Shih-Chên recognises more categories than the *Chhün Fang Phu*, he ignores the three-needled pines, which include some common species, such as Masson's pine.[b] It is noticeable, too, that the pines, unlike some other genera, were not subdivided in traditional Chinese taxonomy into smaller groups to aid in further identification. The pines did not enter directly into the lives of rural people as a cultivated crop until rather late, and so initially it may not have seemed necessary to assign different names to different varieties.

Cultivation of the pines

The pines do not appear as cultivated trees in the earliest agricultural manuals. They were not planted for any more than ornamental reasons until relatively late. One of the duties of the Superintendant of Graves, *Chung Shih*[13], described in the *Chou Li*[c] was to ensure that the correct trees were planted on tumuli. Pines were assigned to Imperial tombs. These trees may have been transplanted from the surrounding hillsides, or they may possibly have been planted from seed, but they were planted for ritual and aesthetic purposes, not to produce timber and other forest products.

The *Chhi Min Yao Shu* only says that pine timber is an excellent building

[a] *CFP, Mu Phu*[14], ch. 1 p. 2b.
[b] *PTKM*, ch. 36, p. 1917.
[c] *Chou Li*, ch. 21, p. 2b.

[1] 潘侯 [2] 柏 [3] 榛 [4] 梧 [5] 樟子松
[6] 紅松 [7] 白皮松 [8] 油松 [9] 馬尾松 [10] 李時珍
[11] 本草圖經 [12] 蘇頌 [13] 冢士 [14] 木譜

material, but does not include it among the trees to be planted on agricultural estates. Harvesting of pines is mentioned in the section on logging, *Fa Mu*[1],[a] suggesting that natural stands of pine were still accessible and supplied sufficient timber to make their cultivation unnecessary. It is only by the Yüan dynasty that the *Nung Sang Chi Yao* has a section describing pine being planted from seed,[b] and detailed instructions for transplanting seedlings are given in the early Ming dynasty *Chung Shu Shu*[2] by Yü Tsung-Pên[3]. There is evidence from poems of the Thang dynasty that pine plantations were being established earlier than this. The *Chhüan Thang Wên*[4] contains a rhapsody by Tshui Tun-Li[5] (fl. c. +650) about planting pines,[c] and Su Tung-Pho[6] (+1037–+1101) is said to have written a detailed account of how to grow pines. This is mentioned by several sources, and is included in the section on pines in the *Ku Chin Thu Shu Chi Chhêng*[7], but it is not found in the current editions of the collected works of Su Tung-Pho. It is one of the few complete accounts we have of the process of planting pines, from seed collection to the establishment of the trees, and is therefore worth including here whoever the true author may be:[d]

After the tenth month, but before the beginning of winter, the pine cones are ripe but have not yet fallen. They should be broken off and stored with their scales in a bamboo container which should be hung in a well ventilated place. If they are not yet ripe, they will not germinate, if they are overripe, then they will be blown and carried away by the wind. In early spring, extract the seeds from the cones, then plant them several inches deep in fallow ground using a large iron dibble, putting several seeds in together. They will germinate during the spring. During this whole process from the selection of the cones to the time of planting, it is best not to challenge fortune. Pines are extremely strong and vigorous by nature, but when they are just beginning to grow, they are extremely fragile and weak, vulnerable to damage from the sun, or to cattle and sheep. This is why they require fallow ground, where the grass will protect them from the sun. If the land has been cleared, then scatter wheat stalks. When several tens of seeds are planted, then the shade of the stalks will allow some of them to survive. Protect the area with thorny scrub and send someone to inspect it every day. They will be ready in three to five years. After five years have passed, their lower branches can be pruned to make them grow taller, and dense growth with small trees can be thinned after seven years to allow them to grow larger.

Pines were never grown with the same intensive methods applied to some of the more commercially valuable species such as the paulownias or cunninghamia. The importance of the pines was not confined, though, to their limited use as timber. All parts of the tree found some use in daily life or in the Chinese

[a] *CMYS*, ch. 55, pp. 317–18.
[b] *NSCY*, ch. 6, p. 100.
[c] *Chung Sung Fu*[8], in *Chhüan Thang Wên*, ch. 135, pp. 17a–18.
[d] *Ku Chin Thu Shu Chi Chhêng*, vol. 547, ch. 197, p. 10b.

[1] 伐木　[2] 種樹書　[3] 俞宗本　[4] 全唐文　[5] 崔敦禮
[6] 蘇東坡　[7] 古今圖書集成　[8] 種松賦

pharmacopoeia. Resin was valued both as an industrial solvent and as a medicine. Li Shih-Chên credits it with curing 'abscesses, ulcers and unpleasant boils, headaches and baldness, scabies and dementia. It soothes the viscera and calms a fever'.[a] An agricultural handbook written in 1903, the *Fu Chün Nung Chhan Khao Lüeh*[1] contains this catalogue which gives an idea of the range of products derived from the pine:[b]

... Its bole can be sawn into planks to make boats or carts ... Branches and needles can be used for fuel, ... its bark and seeds can be used for medicine, pine rosin can be made from the resin. Amber is produced from resin which has been underground for a long time ... Branches which are not suitable for firewood but which contain resin can be used as torches, and small trees can be put in a kiln to extract the smoke and to make charcoal. Branches which give exceptionally clean and delicate soot can be used to make ink.

(ii) Po: *the cypress family*

The family of trees known as the Cupressaceae, includes many genera which have been important in forestry in East Asia (Fig. 119). They include *tshê po*[2], the 'Chinese cedar' or arbor vitae[c] (*Platycladus orientalis* (L.) Franco) in China, and *hinoki*[3], the Japanese cypress (*Chamaecyparis obtusa* Sieb. et Zucc.). The Chinese name *po*[4], refers to a number of different genera and species. Most species with the characteristic scaly leaves of the cypress family were usually given a binomial name including the graph *po*[4]. The most important species are the arbor vitae, *tshê po*[2] (*Platycladus orientalis* L.), a major element of the vegetation of north China, and in more recent times, *phien po*[5], the Chinese name for *Chamaecyparis obtusa*, the Japanese cypress hinoki, an important timber species in Taiwan. In the Chinese sources, *po* usually includes three different groups of conifers. In the north, it refers to *tshê po* (*Platycladus orientalis* (L.) Franco). In the south, it refers to the true cypress (*Cupressus* Spp.). It was also used at times to refer to a juniper (*Juniperus chinensis*) (*tzhu po*[6]), or spiny *po*.

We have already seen that the hinoki is known by different characters in the two languages, and to further complicate the issue, the Chinese character used by the Japanese for *hinoki*[3], pronounced *kuei* in Chinese, is the name given in China to the junipers.[d] Incorrect common names have sometimes been given to Chinese species by reference to works on Japanese botany, such as Kaemp-

[a] *PTKM*, ch. 34, p. 1918.
[b] *Ho Kang-Tê* (*t*), ch. 2, p. 57b.
[c] Formerly known as *Thuja orientalis* L.
[d] Another case of this use of one character to identify different species is the subject of this section; the Chinese character *po* is used in China for the cypress. Pronounced Kashiwa, it is used in Japan as the name for the White Oak (*Quercus dentata*).

[1] 撫郡農產考略 [2] 側柏 [3] 檜 [4] 柏 [5] 扁柏
[6] 刺柏



Fig. 119. Cypress (*po*) trees in the main courtyard of the Confucian temple in Peking. The trees are now some three hundred years old and have been carefully maintained to lend a note of age and dignity to their surroundings (*Platycladus orientalis, tshê po*); orig. photo N. K. Menzies.

fer's *Amoenitatum Exoticarum* of +1712,[a] which first brought species such as ginkgo and hinoki to the attention of European botanists.

The *po* tree is mentioned in early texts such as the *Book of Odes*, where it is sometimes used together with the word *sung*[1], pine, in a combination which may correspond to the English term 'conifers'.[b] Another word which the *Êrh Ya* says is the same as the *po*, is *chü*[2], found in the *Odes* and pre-Chhin texts such as certain sections of the *Kuan Tzu*. The cypress family must have been familiar to the early Chinese since it is often used as a reference in descriptions of less familiar species. The *Shuo Wên* dictionary, for example, describes the juniper (*kuei*[3]) as a tree with 'the foliage of the cypress and the stem of a pine'.[c] In agricultural manuals and botanical treatises, there is usually a section on *po*, under which a number of species such as juniper or cunninghamia are also found.

The Cupressaceae are generally a hardy family, well adapted to dry areas with thin or rocky soils. In modern silvicultural terminology, they are said to be

[a] Kaempfer (3).
[b] Kêng Hsüan (*1*), p. 49.
[c] *Shuo Wên*, Chung Hua edition, 1963, reprinted 1983, p. 118.

[1] 松 [2] 桧 [3] 檜

shade intolerant, needing direct sunlight to germinate and to become established. Tolerance and intolerance to shade were concepts known in early Chinese silviculture,[a] with trees being classified as Yin[1] (shade tolerant) or Yang[2] (shade intolerant). The application of cosmological principles to silviculture carried the seeds of some misunderstanding. The *Chhün Fang Phu*, essentially a literary compendium, refers to the *po* as the only species which are classified as Yin trees. This apparent anomaly seems to be the result of an emphasis in the *Chhün Fang Phu* on the symbolism of the five elements, *Wu Hsing*[3], evident in the preface to the section on 'Wood and Timber' which includes a long discussion by Lu Chia[4] (c. −228–c. −140) on the importance of the element wood.[b] The description of the *po* in the *Chhün Fang Phu* says:

> All trees are classified as Yang, but the *po* is Yin, facing the West. Since it is a wood of rectitude and virtue, we use the character for white, *pai*[5] [in its name]. White is the colour [symbolising] the West.

Li Shih-Chên cites sources from the Wei and from the +11th-century *Phi Ya*[6] by Lu Tien[7] with almost identical explanations.[c] It is not clear why the *po* was said to face westwards, although an ecological explanation might be that west-facing slopes are hotter and dryer than east-facing slopes, and that both juniper and arbor vitae would be better adapted to these conditions than other species.

The classification of the *po* as a Yin species was not universal. Works oriented towards the more practical task of cultivating trees all instructed their readers to treat it in the same way as the pines. Writing in +1639, Hsü Kuang-Chhi[8] addressed the problem in a commentary attached to the instructions for planting cypress in his *Nung Chêng Chhüan Shu*[9]. He notes that Yin and Yang are concepts applied to trees in different ways by different writers, and seems to favour using them as an indication of the time of growth of a tree, with Yin trees growing during the spring and summer, and Yang trees growing during the autumn and winter.[d]

The longevity and stately form of the cypress, with its dark evergreen foliage, lend dignity to important ritual sites in China. The town of Huang Ling[10], in northern Shensi province, is alleged to be the site of the tomb of Huang Ti, one of the legendary early monarchs of China. The tumulus is surrounded by a grove of approximately one thousand ancient arbor vitae said to have been planted at the time of the tomb's construction. It is not possible to say when trees were first planted here, but a stele in the Hsien Yüan Temple[11] at the site, records that in the sixth year of the Chia Yü[12] reign period of the Sung dynasty,

[a] See sections on silviculture (*c*) and ecology (*e*), below.
[b] *CFP, Mu Phu*, ch. 2, p. 17a.
[c] *PTKM*, ch. 34, p. 1913.
[d] *NCCS*, ch. 37, p. 34a.

[1] 陰 [2] 陽 [3] 五行 [4] 陸賈 [5] 白
[6] 埤雅 [7] 陸佃 [8] 徐光啓 [9] 農政全書 [10] 黃陵
[11] 軒轅廟 [12] 嘉祐

(+1062), 'several thousand pines and arbor vitae' were planted to replace dead trees.[a]

Timber that did not decay easily was believed to have special preservative properties of importance in the rituals of death and burial.[b] The inner walls of a Han dynasty tomb at Ta-Pao-Thai[1] near Peking are made of short logs of dressed arbor vitae (*tshê po*[2], *Platycladus orientalis*), with the cut ends turned inwards giving the appearance of a wall of wooden tiles. Construction of the tomb used nearly twenty cubic metres of timber, indicating that then as now, *Platycladus orientalis* was a significant component of the vegetative cover in the hills around Peking.[c]

The earliest reference in an agricultural manual to the *po* is in the +2nd-century *Ssu Min Yüeh Ling*[3] by Tshui Shih[4] where one of the tasks alloted to the seventh month is to 'collect the *po* seeds'.[d] Miao Chhi-Yü[5] believes that this tree is the *tshê po* (*Platycladus orientalis*), whose seeds contain a fatty substance used in medicine. The *Chhi Min Yao Shu* also mentions the *po* tree in its section on logging,[e] but there is no suggestion that the harvested trees had been planted. As with the pines, the planting of cypress, juniper, and arbor vitae is not described until the Yüan dynasty when the *Nung Sang Chi Yao* describes planting *po* from seed, and transplanting it after two or three years.[f] By this time, the fast growing cunninghamia, *sha*[6] of south China was already beginning to eclipse the pines and the cypress in commercial importance, and they never achieved the prominence in forestry that they held elsewhere in Asia and in Europe or America.

(iii) Sha mu: *cunninghamia*

Cunninghamia, *sha mu*[7] (*Cunninghamia lanceolata* Hooker), sometimes inaccurately known as Chinese fir,[g] is the most important conifer planted for timber in south China (Fig. 120). It sprouts readily from the stump after cutting or after fire, which makes propagation relatively easy and encouraged the development of a distinctive silvicultural tradition in south China to take advantage of this physiological characteristic. Its importance can be gauged from the fact that a system of measurement and valuation was devised during the +16th century, specifically for use with cunninghamia timber.

[a] Quoted in Wu Ssu-Thang[8] & Li Ying-Chieh[9] (*1*).

[b] See Loewe (19), for details on beliefs about death and the afterlife.

[c] Details of the excavations at Ta-Pao-Thai had not yet been published in 1986, at the time of writing. I am indebted to Mr. Han Jui[10], curator of the Ta Pao Thai Museum for this information.

[d] *Ssu Min Yüeh Ling*, p. 76.

[e] *CMYS*, ch. 55, p. 317.

[f] *NSCY*, ch. 6, p. 100.

[g] Botanically this name is incorrect. Cunninghamia is a member of the family *Taxodiaceae*, in no way related to the true firs, *Abies* spp., of the family *Pinaceae*.

[1] 大葆台 [2] 側柏 [3] 四民月令 [4] 崔寔 [5] 繆啓愉
[6] 杉 [7] 杉木 [8] 武四堂 [9] 李英杰 [10] 韓銳



Fig. 120. Cunninghamia (*sha mu*) (*Cunninghamia lanceolata* Hooker). Local residents claim that this large specimen at Chhêng Phu, Hu-Nan province was planted during the Thang dynasty; photo Tshao Thie-Ju.

Cunninghamia is not found naturally north of the Chhin-Ling mountains[1] which divide the loess plateau of Shensi province from Ssu-Chhuan. It occurs most commonly in the warm, humid, mountainous areas of southern China growing best in Fukien, Hu-Nan, Chiang-Hsi, Kuang-Hsi, Kuei-Chou, Kuang-Tung, Chekiang, Ssu-Chhuan, Yunnan and An-Hui provinces.[a] The natural

[a] Wu Chung-Lun *et al.* (*1*), pp. 16–18.

[1] 秦嶺山

range of the genus is difficult to define since it has been planted over large areas of southern China, and attempts have even been made to plant it north of the Chhin-Ling mountains in Shensi and Kan-Su. On the whole, these attempts to introduce southern species to the north have not been succesful, and the traveller at the northern limit of the natural range of cunninghamia will see plantations covering the hillsides, growing small, stunted trees popularly called '*hsiao lao thou*[1]' or 'little old men', able only to survive in unsuitable ecological conditions. Plantations are usually located on very steep hillsides, leaving the gentler slopes available for agriculture, although there is evidence that growth is faster on flatter land with richer, more humid soils.

Kuo Phu's commentary to the *Êrh Ya* lists cunninghamia as *shan mu*[2] and describes the durable qualities of its timber which make it particularly useful wherever resistance to decay is required:[a]

Pai Shan[3]. The *Shan*[4] is similar to the pine. It grows in Chiang-Nan [south China]. It can be used to make boats or coffins. Pillars made of it will not rot underground.

Analysis of the timber fragments recovered in a recently excavated Han dynasty boatyard in Canton showed that cunninghamia was one of the woods used in shipbuilding.[b] A number of Han tombs have been excavated in south China, most notably at Ma-Wang-Tui near Chhang-Sha, Hu-Nan province, in which the outer coffin has been found to be of large, thick planks of cunninghamia, whose extractives may have acted as a natural preservative for the contents.[c] The size of these planks indicates that the trees must have been several centuries old when they were cut.

The enormous size attained by isolated specimens of cunninghamia is illustrated by a brief anecdote which occurs in several sources. It is first found in the *Nan Fang Tshao Mu Chuang* which gives no original source,[d] but the *Thai Phing Yü Lan* ascribes it to the *Chiao-Chou Chi*[5] (i.e. Records of Chiao-Chou, the general term used to cover the most southerly parts of China and parts of Vietnam) by the +4th-century Chin dynasty writer, Liu Hsin-Chhi[6].[e] Both versions are very similar, and this translation is taken from the *Nan Fang Tshao Mu Chuang*:[f]

Two hundred *li* east of Ho-Pu[7] there is a *Shan* [*sha*] tree. In the spring of the 5th year of Yung Ch'u[8] (AD 111) of the reign of An Ti of Han, its leaves dropped and were carried by the wind to the city of Loyang. The leaves are several tens of times the size of

[a] *Êrh Ya, Shih Mu*, p. 105.
[b] Kuang-Tung Nung Lin Hsüeh Yüan ... (*1*).
[c] Chung-Kuo Nung Lin Kho Hsüeh Yüan Mu Tshai Kung Yeh Yen Chiu So, 'Kuan Kuo Mu Tshai ti Yen Chiu' (Research on the Wood used for the Coffins), in Anon. (*560*), p. 89.
[d] *NFTMC*, in Li (11), p. 143.
[e] *Thai Phing Yü Lan*, ch. 957, p. 4249.
[f] Transl. Li (11), p. 98.

[1] 小老頭 [2] 楩木 [3] 柀楩 [4] 楩 [5] 交州記
[6] 劉欣期 [7] 合浦 [8] 永初

the ordinary *Sha*. The conjurer Lien Shêng[1] said, 'These are the leaves of the *Sha* East of Ho-pu. This is an auspicious sign that a king will rise there.' The Emperor dispatched an officer to check this and found it true. A thousand men were ordered to cut down the tree and many of the labourers died. Afterwards three hundred men once sat and ate on the stump, without crowding each other. It is still extant today.

With due allowance for literary hyperbole, this story is oddly reminiscent of heroic stories of logging the giant sequoias of California during the 19th century, where the trees were said to be so big that a ball for the whole logging camp could be held on one stump!

The ease with which cunninghamia may be propagated from sprouts must have encouraged the early inhabitants to plant it where it could be more easily tended and used.[a] As with pines and cypresses, cunninghamia was first planted to add dignity and beauty to ritual sites and buidings. According to the gazetteer of Hêng Shan[2], the Sacred Peak of the South, a temple plantation on a large scale was undertaken during the Northern Sung dynasty (+12th century), when the abbot of the *Fu Yen Chhan* (Zen) monastery[3] led his monks in planting trees around the monastery:[b]

[The abbot] then ordered his disciples to plant cunninghamia around the monastery and over an area covering a circle of one hundred *li*. The master said, 'There are remote places on this peak where none of the cunninghamia are in good condition. This means that we cannot be sure of the flow of water and the supply of firewood to our retreat. We must not be remiss in our mission and foolishly fail to make provision for them.

The *Thai Phing Huan Yü Chi* records an early case of type conversion from mixed forest which involved the planting of what must have been a significant area of cunninghamia at Thung-Chhêng[4] district in the Ta Pieh[5] mountains:[c]

The old county town was in the mountains. In the twentieth year of Khai Yüan[6] (+732), it was moved out of the mountains. Dense thickets and brush grew where the former town had been, where wild animals and poisonous snakes had their lairs. This had been troubling the townspeople for a long time so in the eighth year of Yüan Ho[7] (+813), the District Magistrate Han Chên[8] ordered that the grass and trees be burned over and the area planted to pine and cunninghamia.

Traditionally, cunninghamia was planted by selecting and cutting sprouts from the stump of a cut tree or from a tree damaged by fire, and then planting them out where they were required. In some areas, it was grown on a system resembling coppicing, in which the sprouts were left on the parent stump. The

[a] Gabriel Campbell, in a personal communication, reports a similar process in Nepal where farmers select naturally occurring seedlings of useful species, then transplant them closer to their homes where they can more easily be cared for.

[b] *Yüan Chi Nan Yüeh Chih*[9], ch. 19, pp. 24b–25a.

[c] *Thai Phing Huan Yü Chi*, ch. 125, quoted in Phêng Chên-Hua (*1*), p. 4.

[1] 廉盛 [2] 衡山 [3] 福嚴禪 [4] 桐城(縣) [5] 大別(山)
[6] 開元 [7] 元和 [8] 韓愿 [9] 原輯南嶽志

Nung Sang Chi Yao, in +1273, was the first agricultural treatise to describe its cultivation, giving instructions on how to plant cuttings from a parent tree.[a] It is only in the later manuals that the use of stump sprouts is described. Cunninghamia is a very fast-growing tree, and rotations are now usually between fifteen and twenty years in length, though they seem to have been a little longer in the past.[b] The gazetteer of Khai-Hua[1] county, Chekiang province, described rotations of thirty to forty years,[c] and in +1728, the *Ku Chin Thu Shu Chi Chhêng* quoted the gazetteer of Hsi An[2] county (now Chhü county[3] in Chekiang province) which suggests rotation lengths varying from twenty to eighty years depending on factors such as the soil, and prices in the timber markets.[d]

The population in many of the regions where cunninghamia is grown is still composed of significant numbers of groups such as the Miao and the Yao who are ethnically distinct from the majority Han Chinese. Some of these groups are still known as growers and suppliers of cunninghamia timber. A report written in 1938 on forestry in Kuang-Tung described an agroforestry system in which cunninghamia was intercropped with cassava, and the author said that this system had originally been devised by the Miao, to be adopted subsequently by the Han farmers in the same area.[e] Similar systems combining forestry and agriculture were a characteristic feature of cunninghamia plantations, and we shall investigate them in more detail in the following section on silviculture.

(iv) Yin hsing: *ginkgo*

Arguably the best-known Chinese tree outside China, the ginkgo or maidenhair tree is now a familiar ornamental in cities and parks in many parts of the world (Figs. 121*a* and 121*b*). It is one of the many trees described as 'living fossils'[f] which have been discovered in China, but it is perhaps the only one to have been planted extensively before the modern era. *Ginkgo biloba* Linn. or *yin hsing*[4] is a monotypic species, the sole survivor of a family comprising several genera, fossils of which have been found to be most abundant in rocks of the early Mesozoic, with a distribution ranging from the Isle of Mull in Scotland[g] to its present habitat of central China.

[a] *NSCY*, ch. 6, p. 101.

[b] In the most intensively managed plantations of cunninghamia today, the rotations can be as short as eight to twelve years, with the poles being used for scaffolding (Wang Chi-Wu, personal communication).

[c] +1636 *Khai Hua Hsien Chih*, ch. 3, p. 4a.

[d] *Ku Chin Thu Shu Chi Chhêng*, vol. 551, ch. 11, p. 50b.

[e] Pendleton (1). Shaw (1), pp. 57–9, also notes that minority groups were among the major suppliers of cunninghamia timber.

[f] Others include the Dawn Redwood, *Metasequoia glyptostroboides* Hu et Cheng, *shui sha*[5], and *Cathaya argyrophylla* Chun & Kuang, *yin sha*[6].

[g] Steward (3).

[1] 開化(縣) [2] 西安(縣) [3] 衢縣 [4] 銀杏 [5] 水杉
[6] 銀杉

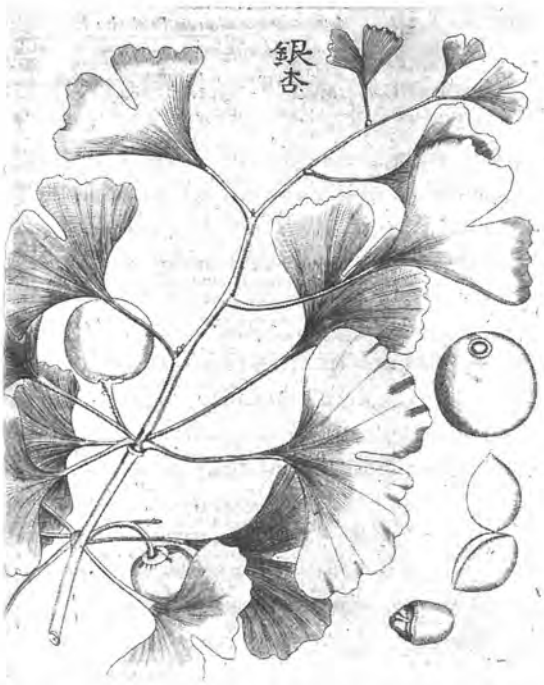


Fig. 121*a*. One of the earliest botanical drawings of ginkgo in Europe; from Kaempfer (3), +1712, p. 813.



Fig. 121*b*. A fully grown, ancient ginkgo tree in China; from Elwes & Henry (1), pl. 23.

Ginkgo is described as a cultivated plant from its first appearance in written records. Other trees are usually first mentioned as growing wild, and it is only later that we hear of them being planted for ornamental or utilitarian purposes. The *Shih Ching*, *Êrh Ya*, and *Nan Fang Tshao Mu Chuang*, our sources of early botanical information, do not mention ginkgo. The earliest undisputed references to the species are from the Sung dynasty, in an exchange of poems between Ouyang Hsiu[1] (+1007 to +1072) and Mei Yao-Chhên (Sheng-Yü[2]; +1002 to +1062), at which time it was already being cultivated in south China as a fruit, which explains why it appears in the botanical works in the section on fruits rather than in the section on trees and timber.

Speculation on the origins and natural distribution of this relic of the past has been encouraged by a dearth of information, and by the absence of any obviously natural stands. Chinese writers have always said that the ginkgo is originally from the area around Hsüan-Chhêng[3] in An-Hui,[a] but this may simply be because it was Mei Yao-Chên's home town. In the exchange of poems with Ouyang Hsiu referred to above, Mei wrote that he had collected the nuts from the wild, so the area of An-Hui does seem to have had some uncultivated specimens of ginkgo during the Sung dynasty.

Western botanists during the 19th century tried without success to identify the native habitat of the ginkgo. Some were inclined to treat as wild almost any specimen distant from obvious human habitation. Mrs Bishop, a natural historian who travelled widely in East Asia, reported in 1899 that she had seen trees growing wild in northeastern Japan.[b] Her claim has not been widely accepted and it is believed that she must have been reporting trees seeded in from a domesticated source, or that she had simply misidentified the tree. At the other extreme was E. H. Wilson, who thought that the species no longer existed at all as a wild species, and put forward the thesis that it owed its survival to the protection afforded it by monasteries. He believed that the ginkgo had a particular association with Buddhism, and that this religious association accounts for its preservation.[c] There is no evidence that this is the case. Ginkgo trees may be found in Taoist temples as well as Buddhist temples, and at many other sites of no specific religious significance.[d] The question of the ginkgo's natural habitat is not yet fully resolved, but it does seem to occur in a mixed coniferous and broad-leaved community in the Thien Mu Shan[4] area.[e]

Known today as *yin hsing*[5], the ginkgo has had a number of other names in the

[a] *PTKM*, ch. 30, p. 1801, quoting the *Jih Yung Pên Tshao*[6].

[b] Quoted in Elwes & Henry (1), p. 55.

[c] Wilson (1), p. 290.

[d] Some writers point out that the ginkgo's association with temples and monasteries is most likely to be the result of the preservation of forest land within their boundaries.

[e] Cheng & Chien (1), p. 299. I have already mentioned in the section on vegetation that the Thien Mu Shan area is a centre of distribution for many rare and endemic species.

[1] 歐陽修 [2] 梅堯臣(聖俞) [3] 宣城 [4] 天目山 [5] 銀杏
[6] 日用本草

past, usually descriptive of the appearance of the leaves or of the fruit. Li Shih-Chên lists it as *yin hsing*, but records *pai kuo*[1] or white fruit, and *ya chiao*[2] or duck's foot as alternatives. The earliest, but far from convincing, reference to the fruit is said to be in the 'Rhapsody on the Capital of Wu' (*Wu Tu Fu*[3]) by Tso Ssu[4] (c. +253 to c. +307) of the Chin[5] dynasty (+265 to +420).[a] The poem mentions a fruit called *phing chung*[6], which a commentator states was of a silvery colour. On this rather flimsy evidence, later botanists infer that Tso Ssu was referring to the ginkgo. Another early, but still dubious claim to age is made for an ancient tree at the Fu-Yen Ssu[7], a monastery on the slopes of the sacred peak of Hêng Shan[8] in Hu-Nan. A stone inscription by the tree says that it was planted by the 'venerable abbot Hui Ssu[9], in the second year of *Kuang-Ta*[10] of the Chhên dynasty[11]'. If true, this tree would have been planted in the year +568. Foresters of the Nan-Yüeh Forest have cored the tree, and a count of the rings indicate that it is actually six hundred years old, a venerable age, but less than half the age ascribed to it by the inscription. Nonetheless, it is not inconceivable that a ginkgo might have been planted by the abbot, and that the existing specimen grows on the same spot.

The exchange of poems between the historian Ouyang Hsiu and his friend the poet Mei Yao-Chên gives us a brief history of the introduction of the ginkgo to north China. This poetic dialogue is preserved in several botanical and herbal compendia, the earliest being the late Sung dynasty *Chhüan Fang Pei Tsu*. Ginkgo is found in the section on fruit trees,[b] and the text consists almost entirely of the poems by Ouyang Hsiu and Mei Yao-Chên. Ouyang Hsiu presented his friend with some ginkgo nuts from a tree which had been planted in the capital, Khai-Fêng[12]. Mei thanked his friend with a poem reminiscing about the ginkgos in his native Hsüan-Chhêng[13]. Ouyang, in return, wrote a poem describing the origins of ginkgo. Both poets refer to the ginkgo most of the time by the name *ya chiao*[14] or duck's foot, descriptive of the distinctive shape of the leaves, although the name *yin hsing*[15] is also used. The historical poem reads as follows:[c]

Ya chio [sic] (duck's foot) grows in Chiangnan with a name which is not appropriate. At first it came in silk bags as a tribute, and as *yin hsing* (silver apricot) it became cherished in the middle provinces. The curiosity and effort of the Noble Prince [Li] brought roots from afar to bear fruit in the capital. When the trees first fruited they bore only three or four nuts. These were presented to the throne in a golden bowl. The nobility and high ministry did not recognise them and the emperor bestowed a hundred ounces of gold. Now, after a few years the trees bear more fruits.

[a] *Wên Hsüan*, ch. 5, p. 10b.
[b] *CFPT*, ch. 7, p. 987.
[c] *Ibid.*, ch. 7, p. 987, or *Ouyang Wên Chung Kung Wên Chi*, ch. 7, pp. 1b–2a. Transl. Li (13), pp. 4–5.

[1] 白果 [2] 鴨脚 [3] 吳都賦 [4] 左思 [5] 晉
[6] 平仲 [7] 福嚴寺 [8] 衡山 [9] 慧思 [10] 光大
[11] 陳 [12] 開封 [13] 宜城 [14] 鴨脚 [15] 銀杏

By the Yüan dynasty, the ginkgo was cultivated as a fruit tree for the nut which became an important product in some areas. The *Nung Sang Chi Yao* (+1273) is the earliest surviving work to give silvicultural details, and these instructions are repeated verbatim in subsequent manuals such as the *Chung Shu Shu*, the *Pien Min Thu Tsuan*, or the *Nung Chêng Chhüan Shu*.

For a horticulturalist or a forester, the most important feature of the ginkgo is that it is dioecious, bearing male and female flowers on different trees. To produce fruit it is therefore necessary to have specimens of both sexes in reasonable proximity. The *Nung Sang Chi Yao* offers a method to distinguish both sexes, and suggests a way of planting to ensure fruiting, with an unusual hypothesis concerning the nature of the ginkgo's reproductive system:[a]

> The ginkgo has male and female trees. The male [seed] has three ridges, the female has two. They must be planted together. When they are planted next to a pond, they face their own reflection and so can bear fruit.

More realistically perhaps, later authors recommend grafting a male branch onto a female tree. There is no tested evidence yet which would confirm that the morphology of the nut is related to the sex of the offspring, although later writers repeated the assertion. As for the advice to plant trees near water, we may smile at the touch of whimsy in the explanation, but it is conceivable that vigorous growth due to proximity to water might produce a heavier crop of nuts than would be the case with trees subject to some degree of water stress. It is ironic, too, that traditional Chinese silviculture of the ginkgo was directed towards producing a crop of nuts, when horticulturists and urban foresters today are trying to devise methods to ensure that they do not plant female trees because the covering of the nuts gives off a very strong smell, considered objectionable in an urban environment.

(2) Angiosperms (Hardwoods)

Forestry tends to be associated with the production of timber, but this is not always the main reason for which hardwoods are grown. Many species bear edible fruits or nuts, some yield valuable products such as lacquer from the sap, or oil from seed, and the Chinese Materia Medica include many medicines extracted from bark, roots, leaves and other parts of trees. It is therefore common to find trees being raised in combination with agricultural crops, in small groups near homes, or in courtyards or even to find individual trees being tended for products other than timber.

The flora of China is rich in trees producing crops of value[b] either directly

[a] *NSCY*, ch. 5, p. 96.

[b] See Wilson (1), chapter 37, for details about the processing of the products of many of these economic species.

from the tree itself (lacquer from the lacquer tree *chhi*[1], *Rhus vernificula* Stokes), or from extracts of the seeds (soap from the seed pods of the soap tree *fei tsao chia*[2], *Gymnocladus chinensis* Baill., and several species of *Gleditsia*), or even from insects parasitic to the tree. Silkworms which feed on the foliage of mulberry or oak are of course the best-known example of the latter.

During the 19th century, European botanical explorers were intrigued to hear about a white wax excreted by insects on trees in southwestern China. The 'wax tree' has two names in Chinese, *nü chên*[3], and *pai la shu*[4]. *Nü chên* is identified by Chhên Chih[a] as *Ligustrum lucidum* Ait., and is the species most commonly described in the botanical works from the +13th-century *Chhüan Fang Pei Tsu* onwards. Li Shih-Chên describes how insects secrete wax on the *pai la shu* in the same way as they do on the *nü chên*, but there are no earlier references.[b] Chhên Chih identifies this as *Fraxinus chinensis* Roxb.

Of more immediate interest to us here are the hardwood species which have been cultivated since early times for their wood. Poems in the *Book of Odes* make it clear that mulberry trees (*Morus alba* L.) were cultivated for sericulture at the time of the poems' composition.[c] To find evidence of trees being planted for timber, we must look forward to the +6th-century *Chhi Min Yao Shu*. Quotations from the earlier manual of agriculture by Fan Shêng-Chih (*Fan Shêng-Chih Shu*) and from the *Ssu Min Yüeh Ling* describe several species still familiar today, including elm, poplar and willow, and the paper mulberry *chhu*[5] (*Broussonetia papyrifera* l'Heritier). Chia Ssu-Hsieh believed that trees were an important component of an agricultural estate, and the sections of the *Chhi Min Yao Shu* concerned with arboriculture could lay claim to being perhaps the oldest extant manual of agroforestry. The popularity of some species waned as the Chinese sphere of influence expanded southward making new types of timber available. It is interesting to note that those species which retained their popularity were those which were particularly prized for a specific purpose, such as the paulownias, renowned for the quality of sound they gave to musical instruments, especially the *chhin*[6].

(i) Yü: *elm*

The original lowland forest cover of north China consisted of a mixed deciduous broadleaved association whose species composition, density and distribution were governed by microclimatic factors.[d] Geographical works such as the

[a] Chhên Chih (*2*), p. 43.

[b] *PTKM*, ch. 35, p. 2011. *NCCS*, ch. 37, p. 39a, says that before the Thang and Sung, wax came from beeswax.

[c] *Shih Ching, Wei Fêng*[7], *Shih Mou Chih Chien*[8], Karlgren (14), no. 111, p. 71.

[d] See (*a*)(2)(i), above.

[1] 漆 [2] 肥皂莢 [3] 女貞 [4] 白蠟樹 [5] 楮
[6] 琴 [7] 魏風 [8] 十畝之間

Shan Hai Ching[1] and the *Shui Ching Chu*[2] may not be accurate guides to the distribution of vegetation, but they can be used as lists of some of the species known to exist at the time they were written. In these texts we read of woodlands on the periphery of the early Chinese State composed of ancestors of domesticated fruits like the peach and mulberry (*Morus alba* Linn.).[a] The elm, *yü*[3] was a component of these woodlands familiar enough to be used as a reference in the description of unknown species:[b]

Fifty-seven *li* to the east is Ta Khu Mountain[4] ... there is a plant there whose leaves are the same shape as elm leaves, with a square stem and green spines. It is called *niu shang* (ox-thorn)[5].

The elms, one genus of the family Ulmaceae, are common throughout the northern hemisphere, with a range extending as far south as Sumatra and Sulawesi in South-East Asia. Some thirty species have been recognised, as well as numerous varieties and hybrids. Related genera of the same family, now found only in China, are *Hemiptelea*[c] and *Pteroceltis*. Elms are sensitive in their requirements for growth. Nutrient status of the soil, temperature and rainfall are all important factors in determining the distribution of a species. The sensitivity of elms to rainfall has made them a useful species in dendrochronological studies of climatic change in Europe, based on comparisons of annual growth rings.[d]

Elms are found in most parts of China, although only the northern species have been used extensively in forestry. *Ulmus pumila* Linn., *pai yü*[6] is particularly common in arid and semi-arid areas, although its range extends to Chiang-Hsi and Ssu-Chhuan provinces in the south and west (Fig. 122). It is known both for the quality of its timber and for its inner bark, used as a source of food in times of famine. Other northern species are *Ulmus davidiana* Planch., and *Ulmus macrocarpa* Hance, while in the more humid, temperate south, *Ulmus uyematsuii* Hayata has been described in Taiwan, and *Ulmus changii* Chêng in Chekiang.[e] It can be very difficult to identify elms in the field since they are variable and hybridise readily, often over great distances. The many varieties of elm to be seen in Britain are now said to belong to only two species, and some of the problems encountered below in identifying the Chinese elms could be due to some writers describing hybrids or varieties rather than distinct species.

We have seen that some conifers were used ornamentally at ritual sites such as tombs, allegedly since the time of Huang Ti[7], the legendary Yellow Emperor.

[a] In the *Shan Hai Ching*, for example, a forest of peach trees is said to exist in the mountains between the modern provinces of Hu-Pei and Ho-Nan; *Shan Hai Ching*, 5, *Chung Tzhu Pa Ching*[8], p. 153.
[b] *Shan Hai Ching*, ch. 5, *Chung Tzhu Chhi Ching*[9], p. 144.
[c] *Hemiptelea* does, in fact, extend into Korea.
[d] Richens (1), chapter 2.
[e] *Ibid.*, pp. 85–7.

[1] 山海經 [2] 水經注 [3] 榆 [4] 大器 [5] 牛傷
[6] 白榆 [7] 黃帝 [8] 中次八經 [9] 中次七經

隰有榆

集傳、榆、白枌也。○說約、榆之類凡十餘種、樞爲刺榆、則榆正總名也、釋木云、榆白枌、孫炎曰、榆白者爲枌、枌亦榆之一種、陸璣釋榆云、白枌也、集傳因之、非是。



Fig. 122. Elm (*yü*); from Mōshī Himbutsu Zukō, ch. 3, p. 12b.

They were not, however, the first trees to be planted to serve human needs for wood products. Hardwoods were grown and utilised for purposes such as supplying weapons or building materials, and also for purposes such as stabilising the dykes used in water-control projects. In the sparsely vegetated northern borderlands between Shensi and Inner Mongolia, defensive barriers were planted to break the force of attacks from Central Asia. The walls between the kingdoms of the Warring States period were in some cases erected behind plantations of elm trees. The *Han Shu* mentions the Elm Valley (Yü Hsi[1]) which was an integral part of the defensive system of the Chhin Great Wall when it was built by General Mêng Thien[2]:[a]

Mêng Thien attacked the barbarians on behalf of Chhin. He advanced several thousand *li*, then with the Yellow River as a boundary, piled rocks into a wall and planted a palisade of elms so that the Hsiung Nu did not dare water their horses at the river.

We may wonder how effective trees would be as a defense against the Hsiung Nu, but the strategic value of forests has frequently been the reason given for protecting or planting forests along the shifting cultural boundary between China and the Central Asian steppes. We will return to this theme in our concluding section on forestry in Chinese society.

Elm appears as an economically important, cultivated species in the *Chhi Min Yao Shu*.[b] Chia Ssu-Hsieh quotes extensively from the earlier, +2nd-century *Ssu Min Yüeh Ling*, so we can be confident that elm was planted commercially during the Han dynasty. By the +6th century, sources of timber were remote enough from urban centres that a market had developed for wood products. Chia Ssu-Hsieh analyses the economic benefits to a landowner of planting elms for timber and firewood and notes the importance of proximity to urban markets:[c]

The land must be close to a city to reduce the labour required in selling firewood, fruit and leaves.

He names four species of elm, the *tshê yü*[3] or spiny elm, the *fên yü*[4] or *fên* elm also known as *pai yü*[5] or white elm, the *shan yü*[6] or mountain elm, and the *chia yü*[7] or *chia* elm. The spiny elm and *chia* elm are recommended as yielding the highest economic return, and Chia Ssu-Hsieh suggests a schedule of rotations yielding different sizes of timber to take advantage of the different prices offered for different size classes.

A reliable identification of the species utilised in the *Chhi Min Yao Shu* may not be possible, but the clues we are given at least allow us to attempt the task. Mountain elm, *shan yü*, may be *Ulmus davidiana* Planch., also known today as

[a] *Han Shu*, ch. 52, p. 2401.
[b] *CMYS*, ch. 46, pp. 272–4.
[c] *Ibid.*, ch. 34, p. 273.

[1] 榆谿 [2] 蒙恬 [3] 刺榆 [4] 枌榆 [5] 白榆
[6] 山榆 [7] 梜榆

black elm, *hei yü*[1]. It is found all over northern China, particularly on rocky, hilly sites and on mountains. The *Êrh Ya* calls it the *ku*[2] elm, saying 'the leaves of the *ku* elm, which grows in the mountains, are round and flattened ...'[a] and *Ulmus davidiana* has the most rounded leaves of the elms of north China.

The white elm, *pai yü*, or *fên* elm, *fên yü*, is usually considered to be *Ulmus pumila* Linn. The timber is of high quality, and the species has long been known as a supplementary source of protein during famines when a white meal is made from the inner bark. This practice is always mentioned in conjunction with the white elm, which is indeed the common name for the species today.

We face a more difficult problem in identifying the spiny elm, *tshê yü*. None of the true elms native to north China is spiny. This may be *Hemiptelea davidii* Plauch., a small spiny tree of the family Ulmaceae, but not of the genus *Ulmus* whose leaves are almost indistinguishable from those of the elms.[b] It is interesting to read in Li Shih-Chên's work, a quotation from the +10th-century *Êrh Ya Shu* by Hsing Ping[3] which says that spiny elm is called *shu*[4] in the *Êrh Ya* and in the *Book of Odes*.[c] The older texts seem to have made a distinction between species which was subsequently lost. It is odd though that Chia Ssu-Hsieh should recommend the species, since it is a shrubby tree, rarely growing to a useful size, and is now considered to be of no commercial importance.

The *chia* elm, *chia yü*, is still more problematic. The only distinguishing feature noted in the *Chhi Min Yao Shu* is that it has a bitter fruit compared to the sweet fruit of other elms. Li Shih-Chên is no more helpful, saying only that *chia yü*[5] (written with a different graph for *chia*) is a large tree. Turning to a list of the elms of north China, I am inclined to believe that if the pincer elm is a distinct species and not a variety, it must be *Ulmus parvifolia* Jacq. This conjecture is based on the observation in the *Chhi Min Yao Shu* that the *chia yü* is an excellent timber tree. It is best grown in rich, moist soils, and the system of cultivation in the *Chhi Min Yao Shu* requires both irrigation and fertilisation. Finally, *Ulmus parvifolia* is relatively slow growing, and the *Chhi Min Yao Shu* recommends growing *chia yü* on a longer rotation than other species.

Elm continues to appear as an intensively cultivated tree in later agricultural works such as the *Ssu Shih Tsuan Yao*, and the *Wang Chên Nung Shu* but it seems that little progress was made sylviculturally, since all authors quote the *Chhi Min Yao Shu* verbatim. More species were identified though, so that by the Ming dynasty, Li Shih-Chên could report that:[d]

[a] *Êrh Ya, Shih Mu*[6], p. 105.

[b] I Chhin-Hêng' in his annotated edition of the *Hua Ching* of +1688 agrees with this identification, pp. 162–3. *Tshê yü* is now the common name for *Hemiptelea*.

[c] *PTKM*, ch. 35, p. 2040.

[d] *Ibid.*, ch. 35, p. 2040.

[1] 黑榆 [2] 姑(榆) [3] 邢昺 [4] 樞 [5] 莢榆
[6] 繹木 [7] 伊欽恒

Hsing Ping says in the *Êrh Ya Shu*: 'There are several tens of species of elm, but nobody can now recognise them all ...

By the time of Li Shih-Chên, elm seems to have lost its commercial importance, appearing low on the list of hardwoods described in agricultural treatises. In the north, the fast-growing, easily propagated willows and poplars continued to be planted, while in the south, forestry was dominated by the conifers and valuable southern hardwoods such as catalpa, *tzu*[1], used for coffins and musical instruments such as the zither (*chêng*[2]), and the paulownia, *thung*[3], used as timber and also for musical instruments, particularly the lute (*chhin*[4]).

(ii) Liu *and* yang*: willow and poplar*

Why plant pines and cassia in white-haired old age,
Expecting some day to see a forest?
I should rather grow poplars and willows,
Enjoying their shade as soon as next year.

[Hsiang Shan[5]][a]

Hsiang Shan was by no means the first person to appreciate the rapid growth of willows and poplars (Figs. 123, 124). Both species appear throughout Chinese literature as a welcome respite from the sun or as familiar landmarks welcoming the traveller home. The image of pussy willow floating lazily on the breeze was used time and time again to evoke the feeling of a warm spring day, and cool avenues of poplars are still planted to moderate the heavy heat of summer in the cities of north China.

Both the willows and the poplars are widely distributed around the world. Once again, China contains an astonishing diversity of species within her borders. Lee Shunch'ing[b] records a total of 121 different species of willow alone. Willows range from the drought-resistant sand willow, *sha liu*[6] (*Salix cheilophila* Schneid.) to species adapted to the warm, moist, semi-tropical southern highlands of Ssu-Chhuan and Yunnan. Both the willows and the poplars tend to be riparian, though some species and varieties are adapted to harsher, more arid habitats. Willows are usually distinguished from poplars by their longer, narrower leaves. Both species release their seed in silky tufts disseminated by the wind, and it could be this common feature which led to some confusion between the species, so that a general binomial '*yang-liu*'[7] or 'poplar-willow' is often found. In literary works, the term generally refers to the willow, while *yang* used alone refers to the poplar. The tendency to refer to *yang* and *liu* to-

[a] In *CFPT*, ch. 17, p. 1229.
[b] Lee (3), p. 179.

[1] 梓 [2] 琴 [3] 桐 [4] 琴 [5] 香山
[6] 沙柳 [7] 楊柳



Fig. 123. Willow (*liu*); from Mōshī Himbutsu Zukō, ch. 3, p. 11b. The caption perpetuates the frequent confusion between *liu*, the willow, and *yang*, the poplar, suggesting that the *liu* is a *yang* with hanging foliage, or even that the two are the same.



Fig. 124. Poplar (*pai yang shu*) (*Populus spp.*). Writers frequently confused the poplar and the willow, but it is clear from the shape of the leaves that this illustration is of a poplar; from *Chiu Huang Pên Tshao*, as reproduced in Chêng Chên-To (*1*), vol. 2, p. 348.

gether is reinforced by similarities in their physiology and their silvicultural requirements.[a]

Many botanical and encyclopaedic works recognised the similarities between poplars and willows, grouping *yang* and *liu* under the same entry. Others felt it

[a] The Chinese were not alone in treating both species together. Ibn al 'Awwām, the agronomist of medieval Arab Andalusia, devotes a section of his agricultural treatise to the poplar and the willow together: '... cultivation of the *naschem*, which is the same as the poplar, *hawar*; the white *naschem*, the black *naschem*; the willow *cifcaf*.' Chapter 7, sec. 53, pp. 375–6.

necessary to distinguish between them. The *Thang Pên Tshao*, quoted by Li Shih-Chên, explains:[a]

Willow is quite unlike poplar. The water poplar, *shui yang*[1], has broad, round leaves terminating in a point, with short, hard branches. Willow leaves are narrow, elongated, and bluish-green, with long flexible branches. When Thao [Thao Hung-Ching, annotator of the *Shên Nung Pên Tshao*] states that willow and poplar are the same, he is wrong.

Another species associated with poplar and willow is the *chhêng liu*[2]. It appears in the poem *Huang I*[3] in the *Ta Ya* section of the *Book of Odes*.[b] The *Êrh Ya* identifies it as '*ho liu*'[4], 'riparian willow' to which Kuo Phu adds, 'This is the small red-stemmed willow found by rivers.'[c] The description given by Li Shih-Chên indicates that this is *Tamarix chinensis* Lour.:[d]

The *chhêng* willow has small weak branches, and grows easily from cuttings. The bark is red, the leaves are as fine as silk and very pretty. It flowers three times a year, with flowers in spikes three to four inches long, pale red like the flowers of the *liao*[5] (*Polygonum*).

The ease with which poplars and willows can be grown from cuttings and sprouts was alluded to by philosophers and statesmen alike. The logician Hui Shih[6] contrasted the ease of planting willows with the difficulty of ensuring their survival to maturity:[e]

Now the willow will grow if you plant it sideways, it will grow if you plant it upside down, it will grow if you break off a branch and plant it. But even if you have ten people planting, all it needs is one person pulling them up by the roots and nothing will grow. So ten people planting the easiest thing to grow cannot outstrip a single man pulling them up.

Willows and poplars have played their part in the continuing task of controlling and managing China's rivers. The *Kuan Tzu* specifies[f] that willows should be planted to stabilise dykes and nearly a millenium later, Yang Ti[7] (Emperor of Sui, r. +605 to +616) ordered that an avenue of willows be planted along the course of the Grand Canal linking north and south China:[g]

[a] *PTKM*, ch. 35, p. 2031.
[b] Karlgren (14), no. 241, pp. 193–4.
[c] *Êrh Ya, Shih Mu*[8], p. 106.
[d] *PTKM*, ch. 35, p. 2035.
[e] *Chan Kuo Tshê*, ch. 7, p. 26b. Transl. Crump (1), p. 404.
[f] *Kuan Tzu, phien* 57, ch. 18, p. 6b.
[g] *Khai Ho Chi*[9], in *KCFP*, ch. 76, p. 4a. This account is not found in the *Khai Ho Chi* as preserved in chapter 92 of *Hsing Shui Chin Chien*[10] by Fu Tsê-Hung[11], which quotes the *Ta Yeh Tsa Chi*[12] on planting willows on the banks of the Canal. On the construction of the Grand Canal, see Vol. 4, pt 3, pp. 306–20.

[1] 水楊 [2] 檉柳 [3] 皇矣 [4] 河柳 [5] 蓼
[6] 惠氏 [7] 煬帝 [8] 釋木 [9] 開河記 [10] 行水金鑒
[11] 傅澤洪 [12] 大業雜集

While the *Pien Chhü*[1] was under construction, hanging willows *chhui liu*[2] (*Salix babylonica* L.) were planted on the dykes on both sides. It was announced that the people would be given a reward of one bolt of double threaded silk for each willow tree. The common people vied with each other to plant them.

We can assume that since the *Kuan Tzu* recommends planting willows, and that if Hui Shih alludes to planting cuttings of poplars, both genera were cultivated well before the appearance of the *Chhi Min Yao Shu* in the +6th century. As was the case with elms, willows and poplars were valuable cash crops. Chia Ssu-Hsieh again gave a detailed economic analysis of the income to be earned by plantations on very short rotations. In the case of poplar, he suggested harvesting the saplings after only three years for sale as canes to be used in the construction of frames to hold silkworm baskets. Five-year-old trees produced rafters for building, and ridge poles could be made from ten-year-old timber.[a] The species commonly used was referred to as the 'white poplar' *pai yang*[3], *Populus tomentosa*, which is and has long been the most commonly planted poplar in north China. In some parts of north China, *pai yang* also refers to *Populus alba* L., while today the term is used rather loosely to describe several different species of poplar.

Four different species of willows are named in the *Chhi Min Yao Shu*: the willow or *liu*[4], the *yang* willow or *yang liu*[5], the *phing* willow or *phing liu*[6], and the osier willow or *chi liu*[7].[b] These names were meticulously copied into later manuals with no further physical characteristics described to aid in their identification. The first willow seems to be *Salix babylonica* L., since the description includes the technique of lopping the top at a height of about ten feet to induce the weeping form appreciated then as now for ornamental purposes. *Yang liu* is said to be appropriate in areas of standing water unfit for grains. No description is given of the tree, but based on its habitat, it could be *Salix matsudana* Koidz., a species known for its tolerance of a high water table. The *phing* willow is mentioned nowhere else, and there is no indication of its appearance or habitat. Its identity can only be left to conjecture. The osier willow could be one of many shrubby riparian species with slender pliable branches. In northern and northeastern China, *Salix purpurea* L., known today as 'red bark' willow *hung phi liu*[8] is widely used to provide materials for basket-weaving.

It is difficult to distinguish different species of poplar and willow, even with a field guide in hand. The *Chhi Min Yao Shu* shows that several different species were recognised and used when appropriate, but later writers seem to have had little time for the intricacies of the dendrology of the Salicaceae. The +10th-century compiler of the *Thai Phing Yü Lan* simply lists references to *yang*,

[a] *CMYS*, ch. 46, p. 274.
[b] *Ibid.*, ch. 50, p. 290.

[1] 汴渠 [2] 垂柳 [3] 白楊 [4] 柳 [5] 楊柳
[6] 憑柳 [7] 箕柳 [8] 紅皮柳

liu or any related species with no attempt at identification.[a] Later still, in the *Chhün Fang Phu* (c. +1621), and the *Kuang Chhün Fang Phu* (+1708), the focus is on improved techniques of cultivation rather than on accurate botanical description. This would be an appropriate emphasis where trees were being grown under silvicultural systems designed to produce wood for specific products. The end product was more important than classifying different species and devising methods to identify them.

(iii) Thung: *paulownia*

Paulownia is very easily identified from descriptions in botanical and agricultural texts, but is at the same time the cause of considerable misidentification and misunderstanding both past and present. The word *thung*[1] refers properly only to species of paulownia, a fast-growing, large-leaved tree found in southern China (Fig. 125). A number of other species exist which include the graph *thung* as a part of their name, and it is with these species that we encounter problems. The most common misapplication of the word is when it is used to refer to the *wu-thung*[2], (*Firmiana simplex* (L.) W. Wight).[b] The *wu-thung* holds an important position in the mythology of trees, as it was said to be the only tree on which the phoenix would alight:[c]

> The Yüan Chhu[3] (phoenix) sets off from the Southern Ocean and flies towards the Northern Sea. It will only alight on the wu-thung tree, and it will only eat the fruit of the bamboo.

The first graph, *wu*, was often omitted from the binomial name, leading some commentators to conclude that *wu-thung* and *thung* were the same tree. The error persisted and, although several later botanists stated categorically that *wu-thung* is not a paulownia,[d] it was still possible for the author of an article written in 1961 to say:[e]

> PAULOWNIA IN THE LEGEND OF THE CHINESE POPULACE. A conventional legend among the Chinese people portrays the paulownia as the only tree on which the phoenix perches ... The phoenix is said to be an auspicious bird which lights only on the best kind of trees and the paulownia meets the requirements.

The +11th-century 'Monograph on Paulownias' (*Thung Phu*[4]), by Chhên Chu[5] lists six varieties of *thung* by name although many of them are in no way related

[a] *Thai Phing Yü Lan*, ch. 956–7, pp. 4145–247.
[b] Formerly known as *Sterculia platanifolia* L., but now reclassified as a member of the genus *Firmiana*, of the family Sterculiaceae.
[c] *Chuang Tzu*, 17, '*Chhiu Shui*[6]', p. 45, line 86.
[d] *PTKM* and *Chih Wu Ming Shih Thu Khao*, for example, both list *thung* and *wu thung* separately.
[e] Hu Hsiu-Ying (14), p. 12.

[1] 桐 [2] 梧桐 [3] 鵷鶵 [4] 桐譜 [5] 陳翥
[6] 秋水



Fig. 125. Paulownia (*thung*) (*Paulownia spp.*), the text refers to the frequent confusion between the *thung* and the legendary roost of the phoenix, the *wu thung* (*Firmiana simplex*), noting that the two are different; Mōshī Himbutsu Zukō, ch. 3, p. 7a.

to the paulownias.[a] There is also one other unnamed *thung* from the seeds of which oil is produced.[b] The first two, white-flowered paulownia, *pai hua thung*[1], and purple-flowered paulownia, *tzu hua thung*[2] are the only two which belong to the genus paulownia. He describes their large, cordate-ovate leaves with the characteristic pubescence, and the durability of their timber. He pays particular attention to the appearance and structure of the flowers:[c]

> The flowers [of the white-flowered paulownia] open before the leaves appear. They are white with a scarlet perianth, deep red inside. The fruit is shiny and smooth when ripe, long and large with a circumference of up to three or four inches; it is divided inside into two chambers, with flesh in each chamber. The flesh is fine white with black dots which are the seeds. It is called the 'white-flowered' *thung*.

The white-flowered *thung* and the purple-flowered *thung* can be identified without too much trouble as *Paulownia fortunei* Hemsl., and *Paulownia tomentosa* (Thunb.) Steudel respectively, both of which are still commercial forest species today. Other names given in the *Pên Tshao Kang Mu* for *Paulownia fortunei* are, *phao thung*[3], or *pai thung*[4] (white thung), and for *Paulownia tomentosa*, *kang thung*[5].[d]

The next *thung* on the list is also easily identified. We are told that the fruit holds between two and four seeds from which a valuable oil is extracted. The same tree is found in the *Pên Tshao Kang Mu* under the heading *ying tzu thung*[6]. Alternative names are *hu-tzu thung*[7], *jên thung*[8] and *yu thung*[9]. The oil extracted from these seeds is *thung* oil, *thung yu*[10], a high-quality paint oil, varnish and waterproofing agent pressed from the seeds of two species of the genus *Aleurites*. *Aleurites fordii* Hemsl., commonly known as three-year *thung*, *san nien thung*[11], is grown as a cash crop in rotation with other crops, occasionally as the first species in a successional system culminating in a timber species such as cunninghamia, *sha mu*[12]. *Aleurites montana* Wils., or thousand-year thung, *chhien nien thung*[13], is often found as a component of home gardens in which a combination of tree crops are grown in the courtyard or around the family home, and it is also used in agroforestry systems, in the same way as *Aleurites fordii*.

Modern taxonomy does not group *Aleurites* among the paulownias, though it is understandable that an early botanist looking at features such as leaf shape and growth form might do so. The inclusion of the thorny *thung*, *tshê thung*[14] in the *Thung Phu*, suggests that in some cases the author relied on previous written sources without having had the opportunity to examine the plant itself. The

[a] Using 'varieties' in its common meaning rather than in its taxonomic sense, where a variety is a subset of a species.

[b] See Vol. 6, pt 1, pp. 169ff. on 'Derivate complexes and coding redundancies', which studies some of the processes by which such complexes developed.

[c] *Thung Phu*, p. 17.

[d] *PTKM*, ch. 35, p. 1997.

[1] 白花桐 [2] 紫花桐 [3] 泡桐 [4] 白桐 [5] 岡桐
[6] 罌子桐 [7] 虎子桐 [8] 荏桐 [9] 油桐 [10] 桐油
[11] 三年桐 [12] 杉木 [13] 千年桐 [14] 刺桐

'thorny *thung*' appears in the *Nan Fang Tshao Mu Chuang* (+304) by Chi Han, referring to the coral tree, *Erythrina variegata* L. var. *orientalis*, or *Erythrina indica* Lam.[a] The *Thung Phu* simply repeats the description of Erythrina in the *Nan Fang Tshao Mu Chuang*, with no further elaboration on the subject. Five centuries later, Li Shih-Chên recognised that it was not related to the paulownias and gave it a separate entry in the *Pên Tshao Kang Mu* with the name *hai thung*[1], sea *thung*, with *tshê thung* given as an alternative name.[b] Still later, another species was included in the *thung* complex, since *tshê thung* and *hai thung* appear as two separate species in the treatise on horticulture and landscape gardening of +1688, the 'Mirror of Flowers', *Hua Ching*[2]. In this case, I Chhin-Hêng identifies *tshê thung* as *Pittosporum tobira* Ait.,[c] a shrub in the family Pittosporaceae native to the warm temperate and subtropical regions of Asia and Australasia.

The entry in the *Thung Phu* for the *wu-thung* (*Firmiana simplex* (L.) W. Wight) is a little puzzling. In the preface, Chhên Chu leaves us in no doubt that he includes the *wu-thung* among the category of trees to be described. The fourth *thung* in the section on 'Varieties' is the *wu-thung*, an ornamental with edible seeds. The entry ends with the statement 'This is not the same as the *wu-thung* mentioned in the *Book of Odes*.'[d] It may be that Chhên could not accept that the tree planted in courtyards and along the streets could have been the legendary roost of the phoenix, but other writers who actually distinguished between *thung* and *wu-thung* were in no doubt this was, indeed the case.[e]

The last two *thung* trees to be mentioned, *chên thung*[3], and *chhêng thung*[4], are in fact synonyms. This is a flowering shrub, the gloryblower (*Clerodendron kaempferi* (Jacq.) Sieb.), native to south China. It is described in the *Thung Phu* in almost exactly the same terms as in the *Nan Fang Tshao Mu Chuang*.[f]

It is now possible to look briefly at the paulownias themselves and at their role in the development of Chinese forestry. Paulownia is considered to be a pioneer species colonising disturbed sites such as abandoned fields, land slides, or road cuttings, but it is not found in large pure stands in natural ecosystems. Its rapid growth and ease of propagation from seed or from adventitious root sprouts would account for its early adoption as a cultivated timber tree. The wood is light, durable and resistant to insect attack. It has traditionally been the preferred wood for making lutes (*chhin*[5]). The *Book of Odes* tells us that the Prince of Chhu[6] planted paulownia around his mansion to provide timber to make lutes.[g]

[a] Li (11), p. 65.
[b] *PTKM*, ch. 35, p. 2001.
[c] *Hua Ching*, pp. 137–8, under *Wu Thung*[7].
[d] *Thung Phu*, p. 22.
[e] Another possibility is that *wu-thung* here might refer to the *Hai Wu Tzu*[8], also mentioned in the *MFTMC*, and identified by Li Hui-lin as *Sterculia nobilis*, Li (11) pp. 128–9.
[f] *Ibid.*, p. 65.
[g] *Shih Ching, Yung Fêng, Ting Chih Fang Chung*, Karlgren (14) no. 50, pp. 32–3.

[1] 海桐 [2] 花鏡 [3] 眞桐 [4] 赪桐 [5] 琴
[6] 楚 [7] 梧桐 [8] 海梧子

The *Chhi Min Yao Shu* includes both the *wu-thung* – which Chia Ssu-Hsieh prefers to call *chhing thung*[1], and the paulownia in chapter 50 where they appear together with *Sophora japonica* L. (*huai*[2]), willow (*liu*[3]), *Catalpa bungei* C. A. Mey (*chhiu*[4]), *Catalpa ovata* D. Don (*tzu*[5]), and oak (*tso*[6]). The most important and informative work on the paulownia, however, is the 'Monograph on Paulownias' by Chhên Chu (+1009 to +1063) already referred to above. The monograph is based on Chhên's own experience cultivating paulownia in the Western Hills (Hsi Shan[7]) near Thung-Ling[8] in An-Hui province. Chhên describes his motives for compiling the work in the Preface:[a]

I have planted paulownia south of the Western Hills, and am now describing all that pertains to paulownia in ten chapters which form my 'Monograph on Paulownias' in one volume. It contains all records about the planting of paulownias in order to make them known to my descendants.

The *Thung Phu* contains particularly interesting sections on planting (*chung chih*[9], section 3), on site adaptation (*so i*[10], section 4), on range and distribution (*so chhu*[11], section 5), and on utilisation (*chhi yung*[12], section 7). This comprehensive treatment, including the silviculture, ecology and utilisation of one genus is remarkably close to what would be expected in a contemporary monograph on a forestry species. It was not until 1847 that American horticulturists learned how to propagate paulownia from root cuttings,[b] although Chhên Chu had described the process in detail almost exactly eight hundred years earlier. The *Thung Phu* must be considered a landmark in the science of forestry, and much of what was said by Chhên Chu during the Sung dynasty can still be applied today.

(iv) Tso *and* li: *oaks*

In the case of paulownia, one name, *thung*[13], did service for a complex of unrelated genera and species which were defined by a binomial term which included the character *thung*. In the case of the oaks, we find a multitude of names applied to different species of the same genus. Anthropologists in the field of ethnobotany have shown that the precision of categories into which plants are classified is dependant on the functions performed by a category of plants. An important species will be identified with precision, and specific names may be used for different forms and varieties of the same botanical species.[c] The list of products

[a] *Thung Phu*, pp. 2–3.
[b] Downing (1).
[c] In Bolivia, La Barre (1) found that the Aymara Indians have some two hundred named categories of their staple food, the potato, La Barre (1). Also see Berlin (1) for some thoughts on the origins of botanical nomenclature.

[1] 青桐 [2] 槐 [3] 柳 [4] 楸 [5] 梓
[6] 柞 [7] 西山 [8] 銅陵 [9] 種植 [10] 所宜
[11] 所出 [12] 器用 [13] 桐

which oaks can provide includes forage, food (acorns), dyes (acorns again), timber and fuelwood, cork from the bark of some species, tannin from the bark of other species. If we consider the extensive geographical distribution of some of the major species of oak in China, and allow for dialectal variation in nomenclature, it need not surprise us to be confronted with a difficult problem of nomenclature.

More than eight hundred species of oaks have been described, including many hybrids. They are found in all parts of the temperate northern hemisphere, extending southwards into the highlands of the tropics. There is still no unanimity on the number of species in China. Lee Shunch'ing recorded fifty-four species in 1935, and a total of one hundred and sixty-four species in 1973, while the contemporary reference work on Chinese taxonomy, *Iconographia Cormophytum Sinicorum* (Anon. 109) lists only forty-eight.[a]

Oak woodland can take the appearance of sparse savannah vegetation, small stands of oak in clumps, mixed broadleaf forest, or pure oak forest. Oaks (*Quercus* Spp.) and their related genera (*Lithocarpus*, *Castanopsis*, *Pasania*) are the most important components of the evergreen broadleaf forest of the south-western provinces. In the dry or semi-arid conditions of north China, oaks are found occupying the cooler, slightly more mesic north-facing slopes, while the south-facing slopes are clothed in a mix of shrubs and grasses.[b] This may have been the landscape in which the early Chinese first cleared the land for agriculture. In the *Chou Li* there is a class of officials appointed to supervise land clearance whose title is *Tso Shih*[1] 'Men of the Oaks'.[c] In the mythic tradition at least, the oak was an early victim of the spread of agriculture and settled Chinese civilisation.

The oaks hybridise readily, and are quite variable in appearance. Some species are evergreen, some are deciduous. Leaves may be large and lobed, or small and serrate to entire. Within one species, an individual may grow to be a tree some ten or twenty metres high, while it may be no more than a low twisted shrub under adverse ecological conditions. The common feature of all the oaks is that they bear their seed as acorns, but they share this characteristic with the genus *Lithocarpus* of the same family.

It would be a vain task and of little benefit to attempt an identification of all the species of oak to be found in the literature. Redundant terms and overlapping names abound, and even in modern Chinese we find that one species may have a different name in different provinces or regions. Consider *Quercus acutis-*

[a] Wang Chi-Wu, in a personal communication, notes that different authors are inconsistent in their treatment of subgenera of *Quercus* such as *Cyclobalanosis*, which accounts for some of the discrepancies in counting the number of species of oak in China. In 1961, [Wang Chi-Wu (1)] Wang listed 75 species of *Quercus* and 119 species of 'oak like' trees. He notes though, that this does not include 'less common species'. Lee (2), pp. 341–81, and Lee (3), pp. 91–113. *Iconographia Cormophytum Sinicorum*, vol. 1, pp. 439–62.

[b] See Lin & Li (1), pp. 20–8, especially sec. 3.

[c] *Chou Li*, II, p. 387.

[1] 柞氏

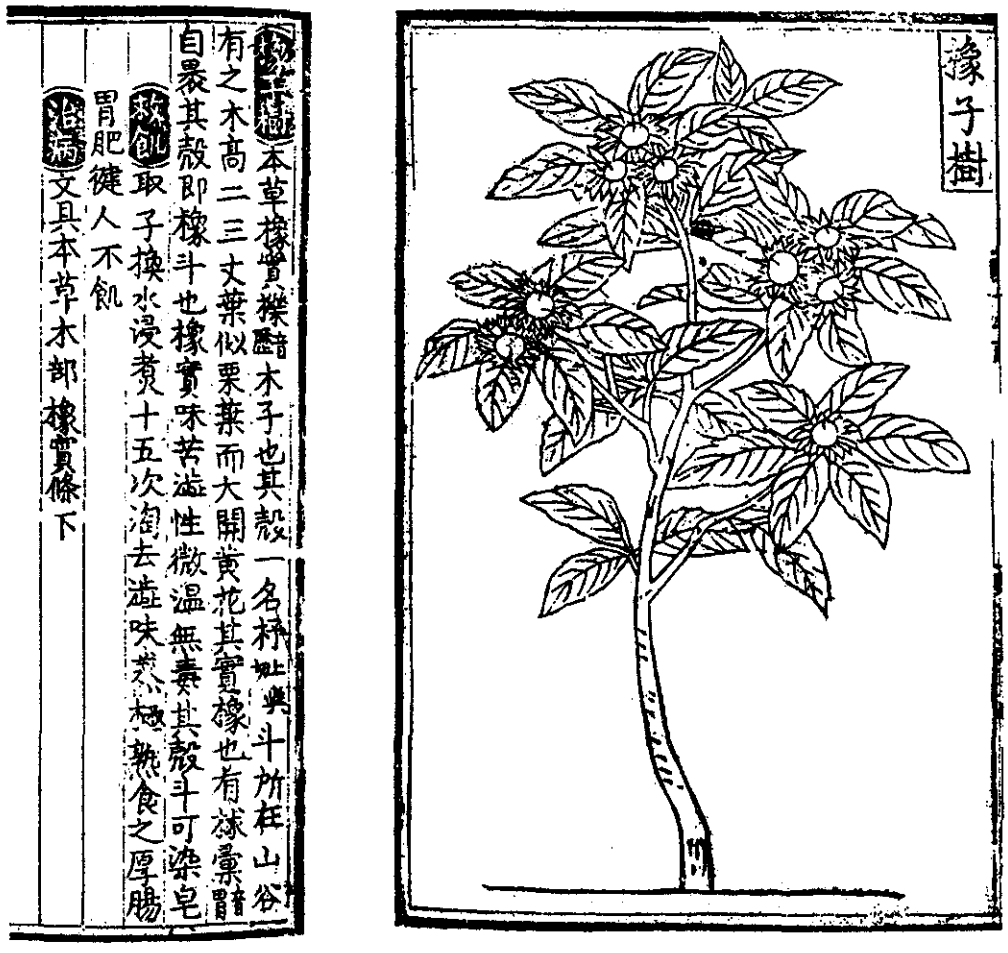


Fig. 126. Oak (*hsiang-tzu shu*) (*Quercus acutissima*). The caption says that the acorns can be used to make a black dye. In times of famine the boiled acorns fill the stomach and 'can prevent a healthy person from starving'; from *Chiu Huang Pên Tshao*, as reproduced in Chêng Chên-To (*1*), vol. 2, p. 392.

sima Carruth., one of the commonest, most extensively used of all the Chinese oaks (Fig. 126). The *Hua Nan Chu Yao Ching Chi Shu Mu*[1], a modern (1976) manual of forestry species for south China, lists *Q. acutissima* under its standard modern name, *ma li*[2]. It then gives some common names for the same species: *chhing kang*[3], *chhai li*[4], *hsiang-wan li*[5].[a] A manual of silviculture, *Chung Kuo Chu Yao Shu Chung Tsao Lin Chi Shu*[6] (Chung-Kuo Shu Mu Chih Pien Wei Yüan Hui (*1*)) gives still more common names; *hsiang shu*[7] (in Chekiang and Shan-Tung), *ta-hsiang-tzu shu*[8] (in Shensi), *po lo*[9] (in Shan-Tung), and *hsiang-tzu*[10] (in Ho-Pei,

[a] Hua Nan Chu Yao Ching Chi Shu Mu Pien Hsieh Tsu (*1*), p. 168.

[1] 華南主要經濟樹木 [2] 麻櫟 [3] 青岡 [4] 柴櫟
[5] 橡碗櫟 [6] 中國主要樹種造林技術 [7] 橡樹 [8] 大橡子樹
[9] 菠欐 [10] 橡子

and again in Shan-Tung).[a] The list of uses of *Q. acutissima* is no less impressive than the list of its names. *Hua Nan Chu Yao Ching Chi Shu Mu* says:[b]

> The timber of *Q. acutissima* is strong, hard-wearing, decay and shock resistant. It is excellent for railway ties, mine props, carts, boats, agricultural tools and furniture. The foliage may be used to feed silkworms; the acorns have a starch content of approximately 50 per cent and can be used to produce methanol, or wine, or as animal feed. Mushrooms can be grown on the twigs and small timber, as well as black fungus (*Auricularia auricula*) and silver fungus (*Tremella fuciformis*). The wood burns with a bright flame and no smoke, and is widely used for charcoal or fuelwood.

Earlier authors have laboured at the task of identifying the oaks described in the classical literature. Table 22 collates the results of their work, giving the current botanical names for each species so far as is possible.

In the Mediterranean region and Northern Europe, the oak has always occupied an exalted position, both symbolically, and in terms of its importance to forestry. European literature draws freely on the imagery of the oaks. They represent strength, integrity and resistance to the ravages of time. Their association with magic and Druidic ritual, whether real or imagined, adds to our respect for their brooding presence in the forest.[c]

In China, by contrast, some of these poetic qualities seem to have been assigned to the pines. The three great botanical compendia, the *Chhüan Fang Pei Tsu*, *Chhün Fang Phu*, and *Kuang Chhün Fang Phu*, give details on planting oaks, culled in the main from the +6th-century *Chhi Min Yao Shu*, and contain a very small number of poems in which oaks are merely mentioned in passing. We learn from Kuo Phu's Commentary to the *Êrh Ya* and from other compilers of botanical works, that some species of oak yield good timber, but they received little attention in the agricultural manuals. The +14th-century *Chung Shu Shu*, which usually contains some original material, or at least draws on sources other than the *Chhi Min Yao Shu*, does not even mention oaks. The *Chhi Min Yao Shu* itself only devotes one small section to the subject in which Chia Ssu-Hsieh mentions that they are planted from acorns, do not require transplantation, and can be used for timber and for firewood.[d]

Turning to accounts by travellers and at least some of the local gazetteers, we find that oaks were, in fact, an important species in the supply of firewood and charcoal. Stands of oak were maintained and managed for a high yield of appropriately sized wood on short rotations, objectives for which coppicing and pollarding are well suited. The gazetteer of Tsun-I prefecture[1] in Kuei-Chou province, in the section on oak sericulture remarks briefly that thinnings from

[a] Chung Kuo Shu Mu Chih Pien Wei Yüan Hui (*1*), p. 500.
[b] Hua Nan Chu Yao Ching Chi Shu Mu Pien Hsieh Tsu (*1*), p. 168.
[c] Wagler (1) documents the role of the oak in German mythology and its cultural legacy.
[d] *CMYS*, ch. 50, p. 293. In modern times, oak is commonly used for making high quality charcoal.

[1] 遵義

Table 22. *Terminology of the Chinese oaks*

These identifications of the oaks most frequently mentioned in the classical literature are based on Bretschneider (*1*), Chhên Jung (*2*), and Chhên Chih (*2*).

Quercus acutissima Caruth.: Modern Name, *ma li*[1]. Known in the literature as: *li*[2]. *Êrh Ya* notes that 'The fruit is a *chhiu*[3] (acorn). *Ku Chin Thu Shu Chi Chhêng*, ch. 236, calls it *hsiang-tzu shu*[4], saying that *hsiang-tzu* is the fruit of the *li*. The *Chhi Min Yao Shu* under the heading *Tso*[5] says this actually refers to the *hsiang*. Chhên Chih says *hsiang* is the same as the *yu*[6] also found in some classical texts, although his only basis for this identification is that it is used in the same way as *Q. acutissima*. This is one of the species of oak that can be used to raise silkworms.

Quercus baronii Skan.: Modern Name, *chiang-tzu shu*[7]. It is known in some areas as *chhing chiang*[8]. Dialectal differences may alter the pronunciation to *chhing kang*[9]. In Ho-Nan this is used for *Quercus spathulata*. Names used in the literature: *Êrh Ya* has *chiang mu*[10], *chan mu*[11], and *kan mu*[12]. Kuo Phu adds that in Chiang-Tung[13] this is known as *mu lo*[14].

Quercus dentata Thunb.: Modern Name, *hu*[15] or *hu li*[16]. Names used in the literature: Kuo Phu identifies *su phu hsin*[17] in the *Êrh Ya* as *hu su*[18]. *Ku Chin Thu Shu Chi Chhêng* has a heading for *Hu*. Li Shih-Chên also includes *pao phu*[19] as variety of *hu*.[a] Chhên Jung says this is *Quercus glandulifera* Bl., and Chhên Chih says it is *Quercus serrata*. Kuo Phu in his commentary to the *Êrh Ya*, and Li Shih-Chên both specify that *pao phu* is a shrubby species. *Q. glandulifera*, *Q. serrata* and *Q. dentata* are all full-sized trees, although they may appear dwarfed and stunted under unfavourable ecological conditions. Since Li Shih-Chên classifies *pao phu* as a variety of *hu*, I prefer to identify it as *Quercus dentata*.

Quercus glaucoides Koidz.: Modern Name, *chhing kang li*[20]. This is of the Subgenus *Cyclobalanopsis*, and is somethimes referred to as *Cyclobalanopsis glaucoides*. Names used in the literature: *chhing kang*[21], *tiao*[22].[b] The name is used for evergreen oaks.

Quercus mongolica Fisch. et Turcz.: Modern Name, *Mêng-ku li*[23]. It is also known in north China as *tso shu*[24]. Names used in the literature: Kuo Phu's Commentary to the *Êrh Ya* has *hsü*[25], and *chu*[26] as alternatives for *tso*, and *Chhi Min Yao Shu* adds *yü*[27] to the list. Li Shih-Chên does not help very much, saying only that a black dye can be made from the acorns of *tso*, when in fact such dyes are made from acorns of several different species. Although *tso* seems to be a generic term for many species of oak, there may have been occasions when it had a more specific meaning. The *Kuan Tzu* does in fact distinguish between *tso* and *li*,[c] which suggests that the name was formerly more specific than it now is.

Quercus serrata Thunb.: See note on *Quercus dentata*.

Quercus spathulata Seem.: See note on *Quercus baronii*.

[a] *PTKM*, ch. 36, p. 2135.

[b] *Shan Hai Ching*, 5, *Chung Tzhu I Shih I Ching*[28], p. 169.

[c] *Kuan Tzu*, XIX, 58, *Ti Yüan Phien*[29], p. 3a.

[1] 厩櫟 [2] 櫟 [3] 梂 [4] 橡子樹 [5] 柞
[6] 楢 [7] 橿子樹 [8] 青橿 [9] 青岡 [10] 橿木
[11] 棧木 [12] 干木 [13] 江東 [14] 木斛 [15] 槲
[16] 槲櫟 [17] 橅樸心 [18] 槲橅 [19] 枹樸 [20] 青岡櫟
[21] 青岡 [22] 楀 [23] 蒙古櫟 [24] 柞樹 [25] 栩
[26] 杼 [27] 栩 [28] 中次一十一經 [29] 地員篇

the coppices on which the worms feed may be used as firewood.[a] Travelling through Chiang-Hsi in 1817, Clark Abel of the Amherst Embassy described seeing extensive plantations of pollarded oaks being grown for fuelwood near Lake Poyang.[b]

The use of oaks in sericulture attracted more attention both from Chinese writers and from foreign observers than the production of fuelwood. Bretschneider looked at some of the trees used in sericulture.[c] Descriptions of oak sericulture are one of the rare sources of information about the silviculture of oaks in China. Several gazetteers describe the cultivation of the oaks, and tending of silkworms (*Antheraea pernyi*) in their sections on 'Produce' (*Wu-Chhan*[1]), and we also have the account of Father Pierre Julien Bertrand, a French missionary based in Chhung-Chhing, dating from 1842.[d] He describes a system in which the oaks are coppiced on rotations of eight to nine years. He implies that the oaks are not planted but that they are grown from sprouts which appear after the trees are cut at the end of a rotation:

> The oaks are not permitted to grow old here, they are cut to ground level every eight or nine years; many sprouts grow out of the roots, and these are cut again after eight or nine years.

More details are given in chapter 16 of the gazetteer of Tsun-I prefecture,[e] which also specifies that oak sericulture was introduced to the area from Shan-Tung province during the seventh year of the Chhien-Lung[2] reign period (1743) by the Prefect, Chhên Yü-Hsi[3], a native of Shan-Tung. We are told too that the oaks are a variety of *hu*[4], which the local people call *chhing kang*[5]. The coppicing process is very similar to that described by Father Bertrand, refined by the use of fire to promote more vigorous sprouting.[f] Although Father Bertrand says the oaks grow in natural stands manipulated for the purposes of sericulture, the Tsun-I gazetteer also gives instructions for site preparation and the planting of acorns, indicating a more intensive level of management.[g]

If the agricultural manuals and botanical encyclopaedias were our only source of information, we would be led to believe that oaks were of little value. Foresters today are sometimes criticised for being mesmerised by fast-growing, high-yielding conifers and imposing a monotonous blanket of plantations on the landscape. It is sad but interesting to see that a narrow perception of 'useful species' is by no means confined to the present, nor to the Western tradition.

[a] 1839 *Tsun-I Fu Chih*, ch. 16, p. 27b. In 1985, Professor Wang Chiu-Ling[6] of the Peking Forestry University told me that in Fang-Shan county[7] near Peking, there are still relict stands of coppiced oak formerly used to grow wood for charcoal.

[b] Abel (1), p. 167.

[c] Bretschneider (14). For information on sericulture see Vol. 5, pt 9.

[d] Bertrand (1).

[e] 1839 *Tsun-I Fu Chih*, ch. 16, p. 17a.

[f] *Ibid.*, ch. 16, pp. 22b–23a.

[g] *Ibid.*, p. 32b.

[1] 物產 [2] 乾隆 [3] 陳玉墀 [4] 櫟 [5] 青岡
[6] 王九齡 [7] 房山縣

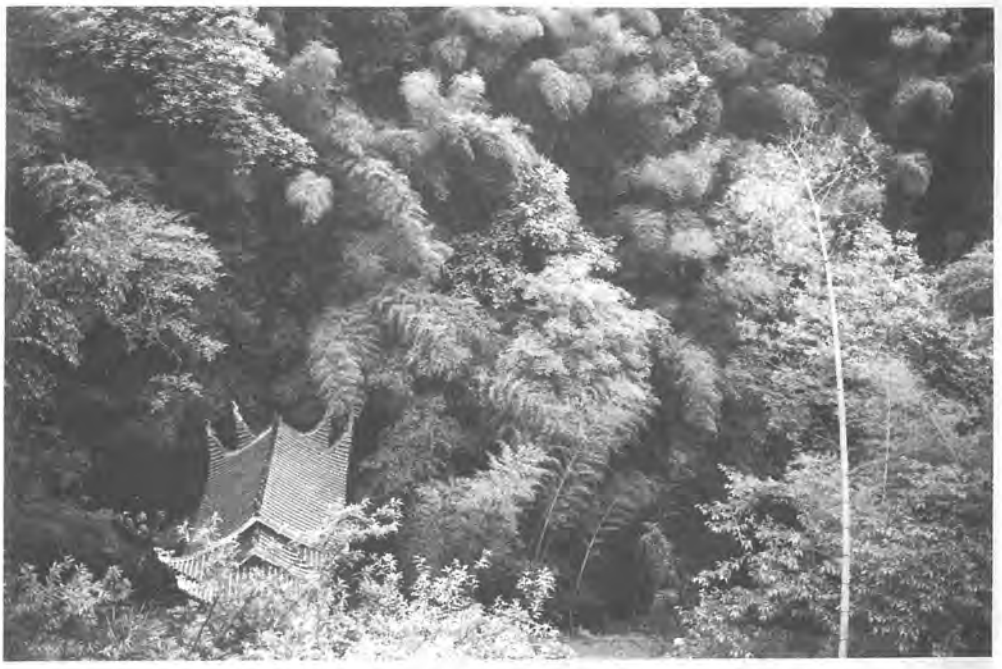


Fig. 127. Bamboo (*chu*). Planted bamboo groves recreate an idyllic natural setting at the Thao Yüan Ming Park, Hu-Nan province; orig. photo N. K. Menzies.

(3) *Chu*: Bamboo

Tall bamboos reflected in the meandering water
So the rippling river drifts blue and green.
We are on the Shang Mountain track unobserved –
Something no woodman would understand.

[Wang Wei (+701 to +761)][a]

It would be hard to imagine the Chinese landscape without the bamboo (Fig. 127). Clumps of bamboo are planted around houses in rural south China, and graceful groves of bamboo line the river banks to form an essential part of the 'Mountain and Water' (*shan shui*[1]) landscapes of the southern Chinese painter. Vegetables held in baskets of split bamboo hang from bamboo carrying poles. Bamboo shoots are a delicate addition to any cooked meal. Scaffolding used for building construction is made of the large stemmed 'Fuzzy Bamboo', *mao chu*[2] (*Phyllostachys pubescens* Mazel ex H. de Lehaie), as are chairs and beds. Ropes woven of bamboo are of open construction and coarse weave. The fibre does not absorb water and dries quickly, making bamboo ropes indispensible for all

[a] Transl. G. W. Robinson, 1973, p. 28. See Wang Wei (1).

[1] 山水 [2] 毛竹

purposes where they are subject to periodic soakings, such as bridges and rafts of logs being floated downriver from the forest.

Bamboos are so closely identified with China and Japan, that when the taste for Chinoiserie swept Europe during the 19th century, bamboo was one of the materials used to give an Oriental touch to any decor. By happy coincidence, it was at this time, in 1839, that the first botanical monograph on bamboos to be published in Europe was printed, in St. Petersburg.[a] The first such work to appear in English was a study, mainly of Indian bamboos, by Colonel W. Munro in 1868.[b]

Ecology and distribution

The Bambusoidae are a subfamily of the grasses, Poaceae. They are found on all the continents except Europe, although only the genus *Arundinaria* is native to all of them. Bamboos are generally restricted to warm, humid temperate or tropical climates, although some species have been found at latitudes as high as 46°N and 47°S.[c] Bamboos pose a peculiar problem of classification because they occupy a position between the trees and the grasses. In the *Shan Hai Ching*, bamboos are always referred to as grasses. The *Chhüan Fang Pei Tsu* includes them in its section on trees, and the *Chhün Fang Phu* avoids the issue by listing them under the rubric 'Economic Plants' together with tea.

Some bamboos are low and grassy, while others grow to be twenty metres tall or more with strong woody culms. There is such a variety of form among the bamboos that it is helpful to describe some of the common morphological and physiological features of the group. McClure[d] has classified the bamboos on the basis of the two major forms of rhizomes which he named leptomorph and pachymorph. Bamboos with leptomorph rhizomes form spreading groves covering large areas in which the culms are evenly spaced. The Chinese *mao chu* (*Phyllostachys pubescens*) belongs to the latter group. Bamboos with pachymorph rhizomes usually form clumps, similar to those formed by perennial bunchgrasses. Other common features of the bamboos are their leaf anatomy, complex branching, and the flower structure.

In most places bamboos are pioneer species, and where extensive tracts of bamboo are seen they represent a seral stage of succession rather than the climax. They commonly take over abandoned fields and bare hillsides immediately after logging. One of their least understood physiological features is the flowering cycle. Most species may live for several decades before flowering and setting seed, after which the whole thicket or clump will die. Tai Khai-Chih, the

[a] Ruprecht (1).

[b] Munro (1).

[c] Soderstrom and Calderon (1), in Numata (2), p. 231. In China, the northern extent of the bamboos' range is at 37° N, in southern Ho-Pei province.

[d] McClure (2), p. 25.

author of the +5th-century 'Monograph on Bamboos' (*Chu Phu*[1]) said that this cycle took place every sixty years:[a]

> The shoots are called *hsün*[2] and the sheaths *tsê*[3],
> In the summer they are numerous and in spring few.
> When the roots and culms are about to rot,
> Blossoms and seeds then appear.
> They are certain to die when sixty,
> And be reproduced in six years.

Contemporary ecologists have not yet been able to identify such a regular cycle of flowering, since each species has a different life span. Nor is it yet known why whole populations of one species will flower and die at the same time. The phenomenon was well known to the early Chinese agronomists for whom it naturally posed a serious problem when it occurred in a plantation. They concluded that flowering occurred as a result of nutrient deficiency in the soil related to overcrowding of the roots. Surviving manuals all follow the *Nung Sang Chi Yao* (+1273) in recommending the addition of fertiliser and thinning the plantation:[b]

> If bamboos flower, they will inevitably wither and die. They will flower and set seed like grass seed, called 'bamboo rice' (*chu mi*[4]). If this happens to one culm then it will spread in due course to the whole plantation. This is the way to control it. When the 'bamboo rice' has just begun, select one of the rather larger culms and cut it about three feet from the roots. You should then pierce through the nodes and fill them with dung. This will stop it.

Chhên Jung[c] suggests that filling the largest culm with dung may be less effective as fertiliser than as an agent inducing more rapid decay of the older bamboos in the stand. Less optimistic, or perhaps more realistic, the *Shu Hsü Pu*[5],[d] two centuries later, recommends cutting down the plantation, fertilising, and starting afresh.

Cultivation of bamboos

The large number of words for articles of everyday use written with the bamboo radical tells us that bamboo was commonly used at least at the time that the written script was being codified and formalised. This again confronts us with the question of climatic change in China over the last two or three millenia. It is curious that bamboo should have been so important in an area where bamboo cannot now survive the cold winters, except under special circumstances such as in sheltered temple precincts and gardens. Bamboos are mentioned in the *Shan Hai Ching* and, more reliably in the *Shih Chi* where Ssu-Ma Chhien

[a] *Chu Phu*, p. 2, transl. Hagerty (1), p. 385.
[b] *NSCY*, ch. 6, p. 100.
[c] Chhên Jung (4), p. 49.
[d] *Shu Hsü Pu*, ch. 10, p. 29b.

[1] 竹譜 [2] 筍 [3] 籜 [4] 竹米 [5] 樹畜部

says 'along the Wei River, the owner of one thousand *mou* of bamboos is of the same degree [of wealth] as the lord of an estate of a thousand households'.[a] By the late +5th century, there is no further mention of these plantations in the *Shui Ching Chu*[1] and a cooling and drying of the climate may have made their continued cultivation impossible.

As befits a plant with so many uses, our sources of information about growing bamboos are scattered between agricultural manuals, monographs on bamboo, books about foodstuffs, and guides to garden design and horticulture. The bamboos have the honour of being the subject of the first monograph in China on a single family of plants. Tai Khai-Chih[2], a native of Wu-Chhang[3] in Hu-Pei, wrote his 'Monograph on Bamboos' (*Chu Phu*[4]) during the +4th century. It contains brief descriptions in the form of rhyming couplets of about forty-seven bamboos.[b] Some of these can be identified on the basis of readily distinguished attributes as in the case of the 'thorny bamboo' (*Bambusa stenostachys* Hack), described as follows:[c]

> The *chi-chu*[5] roots intertwine and grow deeply,
> One clump making a grove.
> Their roots are like the spreading spokes of a wheel,
> And their nodes are like a sheaf of needles.
> They are also called *pa-chu*[6],
> And for city walls they make a certain defence.
> After eating their tender shoots,
> The hair of the head will fall out.

Tai Khai-Chih gives some physiological information about bamboos, such as the concept of the sixty-year flowering cycle, but does not turn his attention to their cultivation. The *Chhi Min Yao Shu* is concerned mainly with growing bamboo shoots, and pays scant regard to producing usable culms. The *Nung Sang Chi Yao*, reflecting perhaps the economic importance of southern China by the Yüan dynasty, has a detailed description of planting, fertilising and harvesting bamboo. This work describes the main elements of bamboo silviculture which are propagation by planting a clump together with its original soil, fertilisation, the problem of flowering, and the need to harvest a clump every other year to maintain its strength and vigour. They reappear with more detail in subsequent agricultural manuals such as the *Chung Shu Shu* and the *Nung Chêng Chhüan Shu*. An amusing recommendation which is repeated in every work on growing bamboos seems to be a method of spot fertilisation:[d]

[a] *Shih Chi, Shih Huo Chih*[7], ch. 69, p. 3272.
[b] The figure is approximate because some descriptions may refer to different varieties of one species.
[c] *Chu Phu*, p. 3, Hagerty (1), p. 390.
[d] *NSCY*, ch. 6, p. 100.

[1] 水經注 [2] 戴凱志 [3] 武昌 [4] 竹譜 [5] 棘竹
[6] 笆竹 [7] 食貨志

... a method to attract bamboos. Bury a fox or a cat the other side of the fence, at the foot of the wall. The next year, shoots will sprout up of their own accord.

It is fitting to close a discussion of species important in Chinese forestry with a class of plants which still defies the neat classifications of Linnaean taxonomy. In the case of bamboos, at least, the Chinese approach to nomenclature seems more appropriate than the Western. All plants whose morphology fits the recognised category of 'bamboo' are given that name, with an identifying descriptive binomial, instead of dividing a recognisable group of plants into several different species with unrelated names.

(c) SILVICULTURE AND FOREST MANAGEMENT

A forest or plantation can provide a continuous supply of wood and other forest products only if cutting and removal of the trees are undertaken according to a plan which allows for the recovery of the resource after harvesting, and for prompt regeneration. Silviculture and forest management guide our manipulations of the forest ecosystem making it possible to manage the forest for timber production, to maintain a varied population of wildlife, for soil conservation, to regulate water flow, or to achieve a combination of these objectives.

In Europe, the fear of a shortage of timber during the +16th and +17th centuries led to the codification of a body of knowledge about silviculture and forest management, and to the recognition of forestry as a profession with institutional status.[a] Plans were drawn up under royal patronage by men such as Colbert in France, in order to regulate the uncontrolled cutting of forest land, and to introduce systems of management designed to ensure a sustainable supply of timber. No such professional body emerged in China, but the absence of a recognised profession does not imply ignorance of the principles and science of forestry. After many years of work in northern China, Lowdermilk wrote, in 1930:[b]

The writer has seen thousands of acres in Anhwei and Honan planted to pine from local nurseries – a practice dating back to ancient time, and quite independent of the modern forestry movement. The village trees, temple forests, and bamboo groves are testimony to a knowledge of and a desire for forest aesthetics and products.

(1) ORIGINS OF SILVICULTURE: MYTH, LEGEND AND ARCHAEOLOGY

The origins of Chinese forestry are closely linked to the clearance of land for agriculture. The grain-based agriculture of the loess plains would have re-

[a] Concern about a timber shortage was related to the enormous consumption of oak by the navies of the time. Baudrillart calculated that in 1825, 100,000 ha. of oak coppice, and 500–600 ha. of high forest had to be cut annually simply to supply the timber needed for repairs and maintenance of the French navy during the +17th century (Badré (1), p. 76).

[b] Lowdermilk & Li (1), p. 3.

quired mobilisation of considerable human effort to remove the natural vegetation and prepare the land for cultivation. There are references in the *Shu Ching* and in the *Book of Odes* to fire being used in land clearance, a form of slash-and-burn agriculture called *fên*[1] in inscriptions on Shang dynasty oracle bones of about the −15th century.[a] Slash-and-burn agriculture is conventionally considered to be the antithesis of forestry, but regeneration of the forest is an integral part of the system, without which the land cannot regain its productivity. In an ecosystem which includes many sprouting species such as oaks, poplars and willows, it is not difficult to imagine the origins of silviculture in the selection and maintenance of certain trees with a view to using their timber at maturity.

The earliest mention of deliberate management of forest resources is found in the legend of Po I[2]. In the *Yü Shu* section of the *Shu Ching* we are told how the mythical emperor Shun[3] laboured to bring order to a chaotic world of floods, overgrown land and wild animals. He appointed trusted men to oversee each aspect of the task, and it is here that we meet our first Chinese forester:[b]

The Emperor said, 'Who is equal to the duty of superintending the grass and trees, with the birds and beasts, on my mountains and in my marshes.' All in the court said, 'There is Yih[4]'. The Emperor said 'Yes. Ah! Yih, do you be my forester.' Yih did obeisance, with his head to the ground, and wished to decline in favour of Choo[5], Hoo[6], Heung[7], or Pe[8]. The Emperor said, 'Yes, but do you go and undertake the duties. You must manage them harmoniously.'

Forest management is a task with some inherent contradictions, as it is concerned with both utilisation and protection of the forest. This conflict is seen even in the case of a legendary hero such as I (Yih). In the *Shu Ching* his instructions are to manage harmoniously. Later, he was remembered by Mencius as the subduer of the wilderness:[c]

Shun committed to I [Yih] the direction of the fire to be employed, and I set fire to, and consumed, the forests and vegetation on the mountains and in the marshes, so that the birds and beasts fled away to hide themselves.

The contrast between these two versions of the same story is interesting evidence that forest management has always wavered uncertainly between conservation and exploitation.

Oracle-bone inscriptions include graphs for several species still grown today, including mulberry, oak and willow. The presence of the 'tree' element in a number of graphs for agricultural words raises the intriguing possibility that trees played a part in Shang agriculture, possibly akin to systems now recog-

[a] See Hu Hou-Hsüan (1), for a study of slash-and-burn agriculture in the Shang dynasty.

[b] *Shu Ching, Yü Shu*, II, i, 22. Transl. Legge (1), p. 46. The word translated here as 'forester' is *yü*[9], defined later in the *Chou Li* as being the officer responsible for forest conservation (see p. 660 below).

[c] *Mêng Tzu, Thêng Wên Kung*, III, i, 4.7, Transl. Legge (3), p. 250.

[1] 焚 [2] 伯益 [3] 舜 [4] 益 [5] 朱
[6] 虎 [7] 熊 [8] 羆 [9] 虞

(*a*) *Yu*: a park, or enclosure



(*b*) *Nung*: agriculture

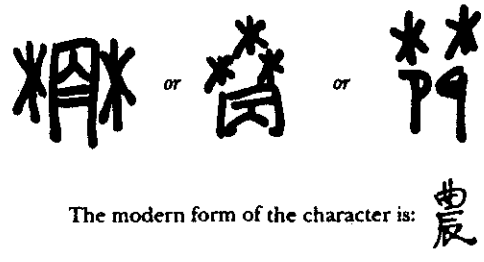


Fig. 128. Early graphs of *yu* and *nung*; from Chang Chün-Chhêng (*1*), p. 182.

nised as agroforestry systems.[a] Figure 128 shows some forms of the words *yu*[1], meaning a park, or enclosure (usually for livestock), and the word *nung*[2] itself, meaning agriculture, both of which clearly included trees in the original graph.[b]

There is considerably more evidence of conscious human manipulation of forests and of tree cultivation by the first half of the −1st millenium, when works such as the *Book of Odes* and the *Chou Li* were composed. We have already seen in the discussion of major forest species that the mulberry and the paulownias were certainly cultivated at this time, and a poem in the *Chou Nan*[3] section of the *Book of Odes*[c] refers to cutting 'branches and shoots' (*fa chhi thiao i*[4]), which Chhên Jung takes to mean that coppicing was being used.[d]

The emphasis of forest management during the early historical period from the Late Chou to the Warring States period and later (−7th century to −3rd century) was on maintaining forest productivity by careful scheduling of timber cutting, with some consideration being given to the phenological characteristics of different species. Prohibitions on cutting, and instructions on appropriate months in which to cut certain species are found in the *Yüeh Ling*[5] agricultural

[a] It would not be very surprising to find agroforestry systems at a time when swidden agriculture still played an important role in agriculture. Grandstaff (1), pp. 11–12, describes swidden systems among the Karen of northern Thailand which include practices such as pollarding, and the retention of seed trees to aid regeneration.

[b] Chang Chün-Chhêng (*1*), p. 182.

[c] *Shih Ching, Chou Nan, Ju Fên*[6]. Transl. Karlgren (14), no. 10, p. 7.

[d] Chhên Jung (*3*), p. 11.

[1] 囿 [2] 農 [3] 周南 [4] 伐其條疑 [5] 月令
[6] 汝坟

calendar in the *Li Chi*.[a] Regulations such as these shed some light on the often quoted passage in Mencius in which the philosopher pleads for cautious utilisation of natural resources:[b]

If the seasons of husbandry be not interfered with, the grain will be more than can be eaten. If close nets are not allowed to enter the pools and ponds, the fishes and turtles will be more than can be consumed. If the axes and bills enter the hills and forests only at the proper time, the wood will be more than can be used.

It is not immediately obvious what Mencius meant by 'the proper time' for entering the forest. Factors determining the timing of timber harvesting include the growth period of trees, and the potential damage caused to the soil surface by disturbance during logging. It is not surprising then, to find different definitions of the 'proper time'. The prohibition in the *Yüeh Ling* on cutting sprouting species during early spring was justified on the grounds that during this season, 'the pneuma of Heaven are descending, and the pneuma of the Earth are on the ascendant, Heaven and Earth are in harmony, grasses and trees begin their growth.'[c] It would be inappropriate to disturb the harmony of Heaven and Earth by cutting trees during this period of growth. This consideration may have some validity if a silvicultural system such as coppicing is being used, in which regeneration depends on the vigour with which the stumps will sprout, although it would not be true if natural regeneration dependant on seed from surrounding trees was being used.

The *Chou Li* presents a different interpretation of when harvesting is permissible. It says that 'Yang trees (*yang mu*[1]) should be cut in mid-winter, and Yin trees (*yin mu*[2]) should be cut in mid-summer,'[d] a statement which was the cause of further controversy. The commentary by Chêng Chung (Ssu-nung[3]: d. +83) says that 'Yang trees grow in the spring and summer, Yin trees grow in the autumn and winter.'[e] The later commentary by Chêng Hsüan[4] (+127 to +200) says that 'trees on southern slopes are called *yang mu*, trees on the northern slopes are called *yin mu*'.[f] It is most unlikely that the growth period of any species in north China would be during the winter, but these two points of view are not incompatible if we remember that north- and south-facing slopes support different vegetation, with evergreen conifers predominating on more xeric south-facing slopes.[g] The persistent foliage of the conifers might lead an observer to believe that they are growing during the winter months.

[a] See the prohibition on cutting sprouting species during the early spring. *Li Chi*, ch. 14, *Yüeh Ling, Mêng Chhun Chih Yüeh*[5], p. 23b. It should be noted that regulations of this type that appear in the *Yüeh Ling* derive more from a desire to achieve cosmic harmony than to ensure effective silviculture.

[b] *Mêng Tzu, Liang Hui Wang*, I, i, 3.3. Transl. Legge (3), p. 130.

[c] *Li Chi*, ch. 14, *Yüeh Ling, Mêng Chhun Chih Yüeh*, p. 21b.

[d] *Chou Li, Ti Kuan*[6], *Shan Yü*[7], ch. 36, p. 11a.

[e] *Ibid.*, p. 11a.

[f] *Ibid.*

[g] Lin & Li (1).

[1] 陽木 [2] 陰木 [3] 鄭衆(司農) [4] 鄭玄 [5] 孟春之月
[6] 地官 [7] 山虞

Among the officials of the idealised Chou administration, as represented by the *Chou Li*, was a group whose duties were to supervise the utilisation of natural resources. Of interest here are the *Shan Yü*[1], or Superintendent of the Mountains, and the *Lin Hêng*[2], the Inspector of the Forests.[a] These officials regulated the times of timber cutting and determined which species could be cut, and they were also responsible for keeping a tally of the number of animals killed in the Imperial hunts – an important first step in the management of wildlife populations. With reference to my earlier suggestion that the original vegetation of north China was closely related to topography, with the denser forests on hills and mountain slopes, it is interesting that the jurisdiction of the *Shan Yü* (Superintendent of Mountains) should encompass 'administration of the forests on the mountains' (*shan lin chih chêng*[3]),[b] while the *Lin Hêng* (Inspector of the Forests) should be charged with 'enforcing the orders of prohibition [of cutting] in the foothills of the mountains' (*hsün lin lu chih chin ling*[4]),[c] which indicates that the problems of forestry in the foothills and in the mountains were seen to be different.

The question of determining the right season to cut timber was raised in most of the manuals on agriculture which followed. The +6th-century *Chhi Min Yao Shu* bases its recommendations on the need to prevent insect damage to the logs, and to ensure an adequate supply of viable seed for regeneration.[d] Similar advice was given in later manuals where decisions about the timing of timber harvesting were based less on a desire to remain in harmony with the annual cycle of nature, than on a need to prevent the loss of valuable timber and to facilitate the growth of a new crop.

(2) The Chhi Min Yao Shu: State of the Art in the +6th Century

In the *Chhi Min Yao Shu* (c. +535), Chia Ssu-Hsieh compiled and edited existing knowledge of agriculture and related rural technologies, adding his own personal comments and opinions. Being a compendium of earlier works, some of which are now lost, it is a convenient point at which to pause to survey some of the characteristics of Chinese silviculture on the threshold of the medieval period.[e]

[a] *Chou Li, Ti Kuan*, ch. 16, pp. 10b–12b. Some other officials in charge of natural resources were the *Hêng Chhuan*[5], Inspector of the Rivers, the *Tsê Yü*[6], Superintendent of the Marshes, and the *Chang Than*[7], Comptroller of Charcoal.

[b] *Ibid.*, p. 11b.

[c] *Ibid.*, p. 12a.

[d] *CMYS*, ch. 55, *Fa Mu*[8], p. 318.

[e] On the sources and contents of the *CMYS*, see Vol. 6, pt 2, pp. 55–9.

[1] 山虞 [2] 林衡 [3] 山林之政 [4] 巡林麓之禁令 [5] 衡川
[6] 澤虞 [7] 掌炭 [8] 伐木

As befits an agricultural manual, the *Chhi Min Yao Shu* is mainly concerned with the propagation and establishment of trees within an agricultural system. It discusses intensive methods of silviculture and very short rotations, concentrating on fast growing, lowland species for which the term 'tree farming' may be more appropriate than forestry, a term associated in the Western tradition with images of extensive natural forests regulated and maintained by the foresters' skills. The *Chhi Min Yao Shu* gives detailed instructions on planting and transplanting trees from seed or from cuttings, and suggests rotation lengths based on the final utilisation of the wood. At the end of the section devoted to tree farming, there is a brief chapter on 'Harvesting' in which the subject of cutting timber from natural forests is touched upon, although there is no indication that management here involved anything more sophisticated than timing the season of cutting to allow natural regeneration to take place.[a]

The chapter devoted to instructions on planting and transplanting trees begins with a warning:

Whenever you plant trees, remember how they are situated with respect to Yin and Yang, and do not alter them. If the positions of the Yin and Yang are reversed (*Yin Yang i chhi wei*[1]), then [the trees] are unlikely to survive.[b]

In this case, the original text makes it clear that Yin and Yang refer to the location of the tree before being transplanted, not to the period of growth or to the season of the year as might have been the case with the Yin trees and Yang trees mentioned above in connection with the Superintendent of Mountains (*Shan Yü*[2]) of the *Chou Li*. Tolerance and intolerance to shade are fundamental concepts in silviculture, and this seems to be the first definite reference to their practical application.

Three methods are given for regeneration in addition to transplanting naturally established trees. These are seeding, vegetative propagation from cuttings or from layering, and propagation using sprouts from a parent tree. The chapter entitled 'Planting Trees' (*Tsai Shu*) is concerned almost entirely with transplanting trees. It is in this section that the only reference to layering is given, although no mention is made of which species were used. Chia Ssu-Hsieh quotes the *Ssu Min Yüeh Ling*[3] of +160, by Tshui Shih[4]:[c]

Tshui Shih says, 'Pare a branch at the end of the first month, or in the second month. At the end of the second month, or in the third month the branch may be covered over.' The branch should be buried in the soil, then two years after a new one has grown it can be transplanted.

[a] CMYS, ch. 55, *Fa Mu*[5].

[b] *CMYS*, ch. 32, *Tsai Shu*[6], p. 207.

[c] In *CMYS*, ch. 32, *Tsai Shu*, p. 208. In this passage, Chia Ssu-Hsieh combined instructions from the first and second months of the *Ssu Min Yüeh Ling's* agricultural calendar, *SMYL Chêng Yüeh*, p. 3, and *SMYL Êrh Yüeh*, p. 26, respectively.

[1] 陰陽易其位 [2] 山虞 [3] 四民月令 [4] 崔寔 [5] 伐木
[6] 栽樹

Whichever method was used to establish seedlings, the ground was first ploughed with as much care as any agricultural crop. Even in the case of oaks (*tso*[1]) which were not considered a very important species, the instructions are 'to plough thoroughly three times' before planting.[a] Seeds were collected and broadcast sown in the same year. The procedure used was common to the elms (*yü*[2]), the oaks (*tso*), *Sophora japonica* (*huai*[3]), catalpa (*tzu*[4]), and many of the fruit trees. The instructions for catalpa (*Catalpa ovata*) give a good idea of the procedure:[b]

Planting catalpa: Thoroughly plough the land in the autumn. Pick the catalpa beans when they are ripe at the end of autumn or in early winter, dry them in the sun and extract the seed. Plough the land to make mounds (*lung*[5]), then scatter the seed and flatten the soil with a brush harrow (*lao*[6]). During the following spring, weed the land to prevent it becoming overgrown. In the fifth month of the next year, lift [the seedlings] and transplant them, allowing two paces between each tree. This is a tree which becomes rather large and the spacing should not be too close.

In some cases germination was hastened by soaking the seed before sowing, and in the case of sophora, the seed was sown together with hemp (*ma*[7]) which acted as a nurse crop forcing the sophora to grow straight and probably also providing protection from frost in winter.

Some species are better adapted to reproduce vegetatively from cuttings than from seed. When possible, and especially when the seed was difficult to collect or to store, this method was preferred to seeding. Willows and poplars were planted in this way and we have already come across the fable by Hui Shih contrasting the ease of planting willow cuttings with the difficulty in raising them to maturity.[c] The method used varied little between species of willow and poplar, consisting of ploughing to prepare the site, followed by planting the cuttings in early spring or in late summer, keeping them well watered, and pruning side branches in the second year of growth. The example of the common willow, *liu*[8], describes the technique in full, with the addition of a recommendation to use fire to cauterise the ends of the cuttings and to stimulate growth of the roots:[d]

Planting willows: From the first month to the middle of the second month, take a supple willow branch of about the thickness of an arm, and one and a half feet long. Cauterise (*shao*[9]) the lower two or three inches, then bury it so that it is completely covered, and water it frequently with adequate water. Several shoots always grow together. Select the shoot with the best growth and pinch off the others. You should also put in an upright pole to act as a support, tying [the shoot] to the pole at intervals of one foot. If it is

[a] *Ibid.*, ch. 50, p. 293.
[b] *Ibid.*, ch. 50, p. 292.
[c] Cf. p. 591, above, in the section on willows and poplars.
[d] *CMYS*, ch. 50, p. 291.

[1] 柞 [2] 榆 [3] 槐 [4] 梓 [5] 壟
[6] 耮 [7] 麻 [8] 柳 [9] 燒

not tied [in this way], then it will be broken off by the wind, unable to support itself. By the middle of the first year it will have grown to a height of at least ten feet. Pinch off the side branches and leaves to allow it to grow straight and tall ...

In the sixth and seventh months, take the small branches which grew in the spring and plant them. They will grow twice as fast. The young branches and leaves are green and vigorous, so they grow fast.

Regeneration from sprouts can take the form of stimulating dormant buds to produce sprouts which are used to produce a new plant, or in the case of coppicing, sprouts growing from the stump of a felled tree are selected to produce one or more new stems on an existing root system. Both methods are described in the *Chhi Min Yao Shu*, with coppicing used for species such as elm and oak which are initially established from seed or from cuttings. It is recommended as an economical and trouble-free way to lengthen the life of a plantation, a free gift from nature which Chia Ssu-Hsieh calls 'working once for endless leisure' (*i lao yung i*[1]).[a]

Paulownias are extremely difficult to grow from seed, and the easiest method of regeneration is to disturb the soil and root system around a parent tree, prompting the growth of new shoots which are then transplanted. Chia Ssu-Hsieh suggests regenerating white paulownia, *pai thung*[2] (*Paulownia fortunei* Hemsl.), in this way:[b]

The white paulownia has no seeds. What appear to be seeds in the winter are next year's buds. In this case, dig a trench around a large tree, remove the shoots (*tsai*[3]) and transplant them.

He also suggests propagating *chhiu*[4] (*Catalpa bungei*) in the same way.[c]

A study of regeneration would be incomplete without some discussion of the deliberate use of fire as an agent to promote vigorous growth in the seedlings. We have already seen that willow cuttings were cauterised to induce root growth. In the case of the elms *yü*[5], and the paper mulberry, *chhu*[6] (*Broussonetia papyrifera*), seedling beds were burned over every year to produce more vigorous growth from new sprouts. Wildfire is generally considered to be a threat to forests, but controlled burning may have beneficial effects in ecosystems and in species adapted to fire.[d] The paper mulberry was initially sown together with hemp which provided the fuel needed to carry the fire, as well as protecting the seedlings during the first months of growth:[e]

In early autumn, when the seeds of the paper mulberry are ripe, collect a large number of them. Clean them thoroughly in water, then dry them in the sun. Plough the land

[a] *Ibid.*, ch. 46, p. 273.
[b] *Ibid.*, ch. 50, p. 292.
[c] *Ibid.*, ch. 50, p. 292.
[d] Cf. p. 627, below, on the subject of cunninghamia in south China. See also Vesey-Fitzgerald (1) and Deval (1) on ecosystems maintained at a seral stage of succession by the use of fire.
[e] *CMYS*, ch. 48, p. 280.

[1] 一勞永逸 [2] 白桐 [3] 栽 [4] 楸 [5] 榆
[6] 楮

thoroughly. Sow in the second month with a drill together with hemp seed, then cover them using the brush harrow. Leave the hemp during the autumn and winter without cutting it, to provide warmth for the paper mulberry. If it is not planted together with hemp, then most [of the seedlings] will be killed by frost. At the beginning of spring the next year, mow close to the ground and burn. Within a year [the seedlings] will all have reached the height of a man. If you do not burn them, they will be weak and growth will be slow.

A hardy tree such as the oak may be sown directly where required,[a] but for most species, seedlings must be transplanted after they have been established in the nursery. The *Chhi Min Yao Shu* gives a lot of information about this delicate phase of cultivation in the instructions for each species, and in the first chapter on tree cultivation entitled 'Tree Planting' (*Tsai Shu*[1]),[b] which is concerned mainly with transplanting naturally established trees such as pines, cypress and bamboo which were not normally grown from seed.

Newly transplanted plants, whether they are three-year-old seedlings or mature trees, are subject to water stress. The loss of water from evapotranspiration is not easily balanced by uptake of water from the soil during the time it takes for the root systems to become established. Chia Ssu-Hsieh suggests a number of ways to reduce water stress, the easiest of which, proposed for the *yang* willow (*yang liu*[2]: *Salix matsudana* Koidz.), is to plant on a cloudy or rainy day and to water generously immediately.[c] Another technique, commonly used today in urban forestry and horticulture, is to remove a portion of the leaves, to reduce evapotranspiration. The 'Tree Planting' section[d] recommends removing the leaves, but the reason given is to minimise the possibility of wind damage. It also stresses the importance of avoiding air pockets near the roots when planting, to ensure that the roots are fully in contact with the soil, facilitating the absorption of water and nutrients:

Large trees should be stripped (*khun*[3]); if they are not stripped they will sway in the wind and die. If they are small they do not need to be stripped. First dig a deep pit. When the tree has been put in place, water it, adding soil to make a fine mud. Shake it well in all four directions for some time. Shaking it allows the mud to penetrate between the roots, and your trees will all survive. If it is not shaken, there will be gaps between the roots and most of the trees will die. Then fill the pit with soil and tread it firmly down. Do not make the top three inches of soil too firm, but leave it loose and porous.

The spacing between seedlings was largely a function of the timber required at the end of the rotation. Planting and harvesting schedules are given for elm, oak and willow, in which the trees were grown on rotations as short as three years for willow saplings used to build frames for rearing silkworms,[e] or as

[a] *CMYS*, ch. 50, p. 293. It is also difficult to transplant oak seedlings because they develop very long tap roots.
[b] *Ibid.*, ch. 32.
[c] *Ibid.*, ch. 50, p. 287.
[d] *Ibid.*, ch. 32, *Tsai Shu*[4], p. 207.
[e] *Ibid.*, ch. 46, p. 274.

[1] 栽樹 [2] 楊柳 [3] 髡 [4] 栽樹

long as twenty years for oak poles used in construction.[a] Some species tend to develop a forked stem or twisted branches if they are allowed a lot of growing space with no competition for light from other trees. This is the case with the elm, and the *Chhi Min Yao Shu* therefore recommends planting them in thickets (*tshung*[1]) for the first three years to force them to grow straight.[b]

Silviculture in the *Chhi Min Yao Shu* was well adapted to the social and economic conditions in which it was practised. Timber was difficult to obtain from the forests, which were in mountainous areas, remote from the urban centres. The economic value of timber grown on agricultural estates made it worthwhile to include tree crops among the staple grains and other market crops, and labour was available to carry out the ploughing, weeding and fertilising required in such intensive 'tree farming'. Later developments in forest management consisted both of refinements and improvements to the intensive systems of the *Chhi Min Yao Shu*, and the gradual development, particularly in South China, of more extensive specialised systems of timber growing.

(3) Developments after the Chhi Min Yao Shu

Agricultural manuals and treatises which appeared after the *Chhi Min Yao Shu* all include a section on tree cultivation indicating that timber was scarce enough to make it worthwhile for a landowner to grow trees on agricultural land. The methods described in the *Chhi Min Yao Shu* were the basis for what followed, to the extent that in a work such as the Thang dynasty *Ssu Shih Tsuan Yao*, the section on trees contains almost no original material at all.[c]

It would be wrong though to suggest that no advances were made in silviculture and forest management after the +6th century. Liu Tsung-Yüan's parable, *Chung Shu Kuo Tho Tho*[2], 'Camel Kuo Tho the Tree Planter,'[d] is evidence that by the +8th century there were tree nurseries with people recognised for their skill in arboriculture. By the +13th century, we read in the *Nung Sang Chi Yao*, compiled by the Imperial Board of Agriculture, that conifers were being planted from seed or, in the case of cunninghamia in south China, from rooted cuttings. With the increasing importance of south China after the Mongol invasion, we also begin to find more information about bamboo cultivation and

[a] *Ibid.*, ch. 50, p. 289.

[b] *Ibid.*, ch. 46, p. 272. In Europe, spacing was an important technique in oak silviculture. When compass timbers (bent timbers) were required for shipbuilding and naval maintenance from the +16th century until the advent of ironclad ships, the distance between trees in oak forest was adjusted to allow wide spacing, allowing the limbs to spread and develop the desired form. James (1), pp. 152–5.

[c] It is possible that timber was more readily available, at least at the beginning of the Thang dynasty which followed several centuries of instability and periods in which north China was dominated by pastoral Central Asian tribes. During this period there had been shifts in the boundary between settled agriculture and pastoralism, and some deforested areas may have reverted to forest, reducing the incentive for landowners to grow trees. Cf. Shih (2), and Chhên Shou-Shih (1), pp. 110–30.

[d] *Liu Ho-Tung Chi*[3], ch. 17, pp. 305–6.

[1] 叢　[2] 種樹郭橐駝　[3] 柳河東集

about extensive systems of forest management in which timber is not simply one component of a diversified agricultural system but is the principal product.

The *Nung Sang Chi Yao* is the first of the agricultural manuals to describe the cultivation of conifers, but we have already seen that pines were planted during the Thang and Sung dynasties. They were grown from seed sown in fallow ground where the grass protected the seedlings from the sun.[a] The instructions in the *Nung Sang Chi Yao* are very similar, with the additional recommendation that ripe pine and cypress cones should be collected in late autumn and stored until the spring when they were to be sown.[b]

In the later manuals we find increasing sophistication in the preparation of nursery seed beds, and more careful selection and preparation of seed for planting. The *Chhün Fang Phu* of c. +1621, introduces the idea of selecting sound seed by soaking in a container and selecting those which sink to the bottom.[c] In some cases seed was given further treatment before planting. The 'Mirror of Flowers', *Hua Ching*[1], published in +1688, suggests coating larger seeds with a protective layer of mud before setting them out in rows in a bed of mixed manure and soil to germinate.[d] The usual procedure for treating and planting seed is described in this way by Hsü Kuang-Chhi[2], in his *Nung Chêng Chhüan Shu*[3] (+1639):[e]

> Just before planting seeds they should be dried in the sun and the clean seed picked out. Soak those which need soaking, while those which are not soaked can be sown directly into the soil. Fine seeds should be broadcast onto the surface of the soil. When they have been sown, fertilise by covering them with manure.

Vegetative propagation of some species by layering, from cuttings, and from root sprouts, was already described in the *Chhi Min Yao Shu*. All these methods were more widely used in the later manuals and in specialised monographs such as the +11th-century *Thung Phu*[4] by Chhên Chu[5]. Willows and poplars had been planted from cuttings from ancient times, but the techniques were developed still further to suit special needs and requirements. Willows, being fast-growing trees adapted to growing in wet soils, were planted to strengthen dykes and canal walls, and hydraulic engineers developed a repertoire of ways to plant out cuttings to achieve objectives such as strengthening the walls, breaking the force of floodwaters, or trapping silt.

Liu Chuang-Hsiang[6], a Ming dynasty administrator with responsibility for flood-control projects on the Yellow River, issued a proclamation on 'Six Ways of Using Willows to Control the River' which is preserved in the compendium of Ming dynasty writings, the *Huang Ming Ching Shih Wên Pien*[7]. In it he explains that willows can be planted either to reinforce the dykes directly, or

[a] Cf. p. 570, above.
[b] *NSCY*, ch. 6, p. 99.
[c] *CFP, Mu Phu*[8], p. 17a.
[d] *Hua Ching*, ch. 2, p. 58.
[e] *NCCS*, ch. 37, p. 33b.

[1] 花鏡 [2] 徐光啓 [3] 農政全書 [4] 桐譜 [5] 陳翥
[6] 劉莊襄 [7] 皇明經世文編 [8] 木譜

to protect land behind the dykes from floodwaters. The first three methods described are used to reinforce the dykes, and the last three use belts of willows planted to break the force of floods:[a]

1 HORIZONTAL WILLOWS (*wo liu*[1]): During the construction of the dyke, long willow cuttings were laid across the earth filling leaving several inches exposed. As the dyke was built up, a layer of willows would be planted with every new layer of tamped earth. The result would be a protective facing of deep rooted vegetation.
2 LOW WILLOWS (*ti liu*[2]): On existing dykes, or when maintenance was not undertaken during the planting season, cuttings could be planted in the dyke walls, working from top to bottom, using stakes for support. Deep rooting systems were again the objective with two feet or more of the cutting buried in the earth.
3 WOVEN WILLOWS (*pien liu*[3]): Used on especially dangerous points on retention dykes at some distance from the river. Starting at the base of the dyke, a row of large willow stakes was planted vertically. Smaller cuttings were planted in a horizontal line at their base. A low fence was woven, using the horizontal cuttings as a base, and the vertical stakes as a framework. The space behind the fence was filled with earth, and new rows of vertical stakes and horizontal cuttings put in at intervals of one or more feet until the dyke was encased in a living armour of willows.
4 DEEP WILLOWS (*shên liu*[4]): A barrier of willows was planted at some distance from the river, in places threatened by the full force of floodwaters breaking over the dykes. Large, straight trees with branches were planted with iron-plated stakes for support.
5 OVERFLOW WILLOWS (*man liu*[5]): Planted to protect areas threatened by the overflow of the river, and by erosion of the banks. Tamarisk (*chhêng liu*[6]) was planted in belts up to ten rows deep. The roots broke the force of the water and collected silt forming natural dykes.
6 HIGH WILLOWS (*kao liu*[7]): Rows of strong, robust tamarisk were planted on the top of dykes to break the force of the overflow during floods.

While specialised uses for willows were being developed in flood control, the number of forest species grown from cuttings was increasing. The *Nung Sang Chi Yao*, in +1273, said that cuttings could be taken from oaks, and conifers.[b] The section on pines contains subsections on cypress (*po*[8]), juniper (*kuei*[9]), and cunninghamia (*sha*[10]) in which cunninghamia and juniper were both propagated

[a] *Huang Ming Ching Shih Wên Pien*, ch. 157, *Phing Lu Thang* edition, vol. 10, pp. 790–6.
[b] *NSCY*, ch. 6, p. 101.

[1] 卧柳 [2] 低柳 [3] 編柳 [4] 深柳 [5] 漫柳
[6] 檉柳 [7] 高柳 [8] 柏 [9] 檜 [10] 杉

from cuttings. Cuttings for cunninghamia were taken from young branches, while juniper was grown from stump sprouts:[a]

Juniper can be planted in the same way as pine. Planting cuttings: In the second or third months, when sprouts begin to appear on the stump, use a mattock (*shu*[1]) to prepare a field of yellow soil thoroughly and form a bunded field (*kuei*[2]). Let water into the field, and when it has soaked [the soil], let in water a second time. Wait until it has the consistency of mud, then cut the juniper in lengths of one and a half feet. The cut end at the bottom should be shaped like a horse's ear. Make a hole in the mud with a staff and insert the juniper cutting into the hole to a depth of between five and seven inches or more..They should be planted close together and watered frequently to keep [the soil] moist and humid. Protect them from the sun by covering them with a small awning (*fhêng*[3]), which should be replaced by a coldframe in winter which should be removed in the second or third month of the following year. Wait until the trees have grown in height then transplant them in the same way as pines or cypress.

The *Chhi Min Yao Shu* noted the difficulty of collecting and germinating paulownia seed, suggesting that root sprouts should be planted instead. Not surprisingly, the *Thung Phu*[4], 'Monograph on Paulownias' by Chhên Chu[5] goes into more detail on the subject. The third section of the monograph explains that seeds sown on manured soil will grow very fast, but that they are liable to blow away due to their small size. More practical and equally successful methods were layering, planting cuttings, and root sprouts selected after disturbing the surface root system:[b]

If fast growth is required, then hoe the area under a paulownia tree, cutting the surface roots (*man kên*[6]). The roots will sprout where they have been cut, more vigorously than those grown from seed, and they can be propagated again in the same way.

(i) *Transplanting and maintenance*

He answered, 'I, Tho Tho, cannot give longevity to a tree or make it bear sprouts. I can only comply with what Heaven ordains for the tree, using its own nature to achieve [what is desired]. It is in the nature of trees that when they are planted, their roots should be spread out, the earth should be banked up evenly, they should be planted in the soil from which they originally came, and the soil should be pressed firm. Then let nature take its course.'[c]

Couched in the language of metaphor, the tale of Camel Kuo Tho the tree planter outlines some of the precautions to be taken when transplanting seed-

[a] *NSCY*, ch. 6, p. 100. It later became more usual for cunninghamia to be grown from stump sprouts. Cf. p. 628, below. The *KCFP* says cypress may also be grown from cuttings. ch. 71, p. 18b.

[b] *Thung Phu, Chung Chih*[7], p. 27.

[c] Liu Tsung-Yüan, 'Camel Kuo Tho the Tree Planter' (*Chung Shu Kuo Tho Tho Chuan*). *Liu Ho-Tung Chi*[8], ch. 17, p. 306.

[1] 斲 [2] 畦 [3] 棚 [4] 桐譜 [5] 陳翥
[6] 蔓根 [7] 種植 [8] 柳河東集

lings. It is important to ensure that the root systems develop rapidly, and this is what is meant when Camel Kuo Tho says that the 'roots should be spread out', which would increase the surface area of roots in contact with the soil. In the early +14th century, Yü Tsung-Pên[1] in his 'Manual of Arboriculture', (*Chung Shu Shu*[2]), suggests cutting the tap root, which acts mainly as a mechanical support for the plant, to promote the growth of fine side roots which are more efficient at absorbing nutrients.[a] Another technique, recommended by Yü Tsung-Pên and found in later works such as Hsü Kuang-Chhi's *Nung Chêng Chhüan Shu*[3], was to coat the roots in mud which would protect them from dessication during transplanting.[b]

Trees require continued care and maintenance once they have been planted out if they are to produce timber of the highest quality. Appropriate spacing, regular pruning, judicious applications of fertiliser and irrigation were all part of the silvicultural systems described in the agricultural manuals. The descriptive essay on planting pines ascribed by the *Ku Chin Thu Shu Chi Chhêng*[4] to Su Tung-Pho[5],[c] includes the remark that 'After five years have passed, their lower branches can be pruned to make them grow taller, and dense growth with small trees can be thinned after seven years to allow them to grow larger.' This statement shows an awareness of the importance of correct spacing and of pruning.[d]

Pruning must be carefully done if the form of the tree is to be enhanced and not harmed. Rough pruning which leaves dead, broken branches, causes knots to form, weakening the timber, and creates a pathway for disease to enter the tree. Chhên Chu's[6] *Thung Phu*[7] of +1049 is careful to warn against bad pruning and to explain to the paulownia grower how the work should be carried out:[e]

> Wait until [the branches] have grown, then climb up the tree and use a sharp knife to cut them close to the stem, taking care not to leave any broken-off stumps. After two spring seasons, the bark will have healed naturally.

Fertilisation and irrigation of the growing seedlings are mentioned in all sources. The 'Division of Livestock and Trees', *Shu Hsü Pu*[8], by Sung Hsü, published in +1504, treats the subject in the most detail. Sung Hsü follows his predecessors in advising the use of liquid manure when transplanting seedlings, then gives a recipe for a very potent-sounding brew which includes pigs' urine, and a liquid called 'goose feather soup' (*ê ling thang*[9]) composed of goose feathers, Litchi kernels, and rotted Longan.[f] Wisely, he warns that this fertiliser should not be allowed to touch the tree itself!

Once the trees were well established and past the seedling stage, they were

[a] *CSS, Mu*[10], p. 37.
[b] *Ibid.*, and *NCCS*, ch. 37, p. 31a.
[c] Cf. p. 570, above.
[d] In *Ku Chin Thu Shu Chi Chhêng*, vol. 547, ch. 197, p. 10b.
[e] *Thung Phu, Chung Chih*[11], p. 32.
[f] *Shu Hsü Pu*, ch. 9, p. 2a.

[1] 俞宗本 [2] 種樹書 [3] 農政全書 [4] 古今圖書集成 [5] 蘇東坡
[6] 陳翥 [7] 桐譜 [8] 樹畜部 [9] 鵝翎湯 [10] 木
[11] 種植

rarely fertilised or irrigated.[a] The exception was in the case of mulberry and oak trees used in sericulture which were subjected to frequent defoliation to provide leaves to feed silkworms. The *Chhi Min Yao Shu* describes an elaborate system of cultivation which includes the use of green fertiliser, regular dressings of silkworm droppings, and the use of pigs foraging underneath the trees to loosen and fertilise the soil.[b] Over a millenium later, the 19th-century gazetteer of Tsun-I prefecture includes an account of oak sericulture in which the vigour of the coppiced trees is maintained by the application of pigs' blood.[c]

(ii) *Management systems*

The intensive systems of tree cultivation described in the agricultural manuals were nearly all planned as even-aged plantations to be cut and replanted at the end of each rotation. Coppicing systems, in which the existing root system of the parent stump speeds the process of regeneration, were less common. This may be a slightly distorted picture given by the agricultural bias of our sources. Where trees were being grown within an agricultural system, landowners may have been unwilling to keep one piece of land in the same crop for a long period of time, and would have preferred to plant out seedlings in fields according to a rotation schedule designed for the food crops which were the mainstay of the estate's economy. The objective of most coppice systems is to produce a regular supply of wood without having to re-establish new trees. They are commonly used in rural areas to produce firewood or wood for charcoal, and are unlikely to appeal to the readership of agricultural manuals whose interest lay in the production of wood products on a commercial basis.

Coppicing is mentioned in the *Chhi Min Yao Shu* as an unexpected bonus from nature following the harvest of willows and oaks – both of which were grown in areas unsuitable for grain crops.[d] The method used to grow juniper from stump sprouts described in the *Nung Sang Chi Yao*[e] is derived from coppice management, but the sprouts are removed from the tree and planted elsewhere, whereas in true coppice systems vigorous sprouts are selected and left to grow to the desired diameter. Stump sprouts usually develop after the parent tree has been cut but dormant buds can be activated by other forms of injury such as fire. Camphor (*chang mu*[1]) was one economically valuable species which was sometimes regenerated from sprouts after the stump had been burned. Both true coppice and the use of stump sprouts were later used in the extensive man-

[a] This stands in contrast to medieval Andalusia, another area of timber scarcity, where some species were grown to maturity in irrigated systems. Cf. Ibn al 'Awwām, chapter XII, pp. 534–6.
[b] *CMYS*, ch. 45.3 and 45.5, pp. 262–3.
[c] 1839 *Tsun-I Fu Chih*[2], ch. 36, p. 33b.
[d] *CMYS*, ch. 46, p. 291.
[e] *NSCY*, ch. 6, p. 101.

[1] 樟木 [2] 遵義府志

agement of cunninghamia in south China which we will examine in more detail later.

Pollarding, the practice of lopping a tree at a height of about two metres, then selecting sprouts which develop in the same way as in coppice, is usually used now for aesthetic purposes. It is however a common form of management seen in villages all over the world. H. L. Edlin has suggested that in the commons forests of medieval England, coppices were in danger of being browsed by livestock. Pollarding allowed the commoners to enjoy both timber and grazing on the same land by putting the tender shoots out of the reach of the animals.[a] Another advantage of pollarding is that the owner of the tree can cut small sizes of timber for several years while waiting for the main stem of the tree to grow large enough to be used as a sawlog. It is used in this way in areas of particularly acute timber shortage and pollarded trees are the only trees to be seen in villages in the arid parts of Tibet, or in the oases of the Tarim basin. The agricultural manuals are silent on the subject, but travellers' reports from the 19th century indicate that pollarding was widely used. Clarke Abel, who accompanied the Amherst Embassy to China in 1816 and 1817, saw plantations of pollarded oak north of Nan-Ching.[b] Chhên Jung also describes an unusual variant of pollarding used near Yi-Hsing where pine trees were being grown to supply firewood for the porcelain kilns. Limbs were trained for several years to grow horizontally, then branches were selectively cut when they had grown to a suitable size.[c]

Whatever the system of management, it is a feature of Chinese silviculture that the length of a rotation was defined by the end product for which the timber was being grown. Economic factors could determine the choice of final product, and thus affect the length of the rotation but timber was not usually perceived as a long-term investment. The present paradigm of forest economics holds that growing timber represents fixed capital with an opportunity cost measured by the current interest rate. The value growth rate of a forest should exceed the interest rate, or the growth rate of capital. It is interesting to read, though, of traditional practices and customs in China which do treat trees as an investment. There are many accounts from south China that trees were planted at the birth of a daughter, to be cut and sold at the time of her marriage to pay for the wedding expenses and the dowry. The tradition is described here – albeit referring instead to the birth of a son – in an article from the Reforestation Movement of the early years of the Republic:[d]

> The custom is that of starting a forest plantation at the birth of a male child. The plantation so started is generally cut when the boy is old enough to marry. The money used from selling the trees is used to defray the wedding expenses of the boy.

[a] Edlin (1), p. 104.
[b] Abel (1), p. 164.
[c] Chhên Jung (2), pp. 52–3.
[d] Lin, Dauyang (1), p. 78.

(4) Specialised Management Systems: Bamboo and Cunninghamia

(i) *Bamboo*

The cultivation of bamboos requires a form of management adapted to the peculiar physiology and ecology of the sub family. One bamboo clump, or clone, may be very long-lived, but the average lifespan of each culm may be no more than about ten years before it becomes brittle and useless as timber.[a] Flowering and seeding are still poorly understood so that regeneration from seed is for most practical purposes not possible since flowering is followed by the death of the plant.[b] A further consideration is that bamboo is often grown both for timber and as a food crop. Both products have a high market value, allowing even greater intensity of labour than we have seen for tree crops within agricultural systems.

Archaeological and literary evidence both show that objects of ceremonial and everyday use were made from bamboo in earliest times.[c] The +4th-century monograph on bamboos, the *Chu Phu*[1] by Tai Khai-Chih[2] is a valuable guide to the species of bamboo known and used at the time, but it contains little information about their cultivation. Most of the section on bamboos in the +6th-century *Chhi Min Yao Shu*[d] is concerned with bamboo shoots, suggesting that bamboo was first cultivated for consumption. This is misleading, since according to the *Shih Chi*[3] five hundred years earlier, during the Han dynasty, large plantations of bamboo existed in the Wei river valley.[e] More profit was earned from these plantations, according to Ssuma Chhien[4], than could be earned from agriculture, suggesting that, at that time, bamboo was grown in the north for timber rather than for the edible shoots.

Bamboo should be grown in rich well-drained soil. This makes it a suitable crop for hilly regions, and some of the most important bamboo-producing areas today are in the rugged mountains of Fukien, Hu-Nan, Chiang-Hsi, Kuang-Hsi and Ssu-Chhuan provinces. The *Chhi Min Yao Shu* described bamboo as:[f]

> ... suited to high but level places. It is particularly suitable for areas near mountains and hills. If it is planted near low-lying fields with a lot of water it will die. Loose yellow-white soil is the best.

[a] Numata (1), p. 228.
[b] Cf. pp. 604–5, above, for a discussion of the knowledge of bamboo physiology in China and about flowering.
[c] For a survey on the role played by bamboo in Chinese civilisation, see Hsiung Wên-Yü (1).
[d] *CMYS*, ch. 51.
[e] *Shih Chi, Shih Huo Chuan*[5], ch. 69, p. 3272.
[f] *CMYS*, ch. 51, p. 297.

[1] 竹譜 [2] 戴凱之 [3] 史記 [4] 司馬遷 [5] 食貨傳

To improve drainage of the area immediately surrounding each culm, Yü Tsung-Pên[1] in his 'Manual of Arboriculture', the *Chung Shu Shu*[2] of the +14th century, recommends banking up the earth around each plant into a mound two or three feet high.[a]

The most common way to propagate bamboo is to dig up a parent culm with a section of rhizome and to transplant it where required. After a year or two, the spreading rhizomes send up new shoots which may be cut for eating or left to form new culms. Other methods are known and used, including root sections, planting cuttings taken from dormant buds at the nodes on a culm, and even seeding in the case of some species which flower and seed at fairly short intervals.[b] With the exception of root cuttings, mentioned in the Ming dynasty (+1640) *Yang Yü Yüeh Ling*[3] by Tai Hsi[4], these alternatives are not found in the literature.[c]

Instructions for transplanting bamboo are given in the *Chhi Min Yao Shu*, with similar accounts found in all later works:[d]

> During the first and second months, cut the rhizomes which run from east to west together with their shoots and strip off the leaves. Plant them in the northeastern corner of the garden. Prepare a trench about two feet deep and cover [the transplanted bamboo] to a depth of five inches ... Use rice or wheat stalks as compost. They should be used separately not mixed together. Do not water [the bamboo]. If you water it, it will be waterlogged and die. Keep livestock out of the garden.

The *Chung Shu Shu* gives the same instructions, but in the calendar of agricultural activities, we also find a note for the fifth month which says, 'Plant bamboos. The thirteenth is the most suitable day. It is called 'the day of the drunken bamboos' (*tsui chu jih*[5])'.[e] Chhên Jung suggests that different seasons are appropriate to different varieties of bamboo. In general, bamboos with leptomorphic (spreading) rhizomes are best planted in early spring, and bamboos with pachymorphic (clump) rhizomes are more suited to summer planting.[f] Later manuals recommend the same basic technique, elaborating a little on the precautions to be taken to ensure a high rate of survival. The *Chung Shu Shu* puts its advice in the form of four paradoxes:[g]

[a] *CSS*, p. 27.

[b] A contemporary manual on the management of the *mao chu*[6] (*Phyllostachys pubescens* Mazel ex H. de Lehaie.) recommends seeding if large areas of land are to be planted to bamboo. Cf. Shang Yeh Pu Thu Chhan Tsa Phin Chü (1), p. 24.

[c] Quoted in Chhên Jung (4), p. 208. The technique was said to have a poor success rate and was not recommended.

[d] *CMYS*, ch. 51.2, p. 296.

[e] *CSS*, p. 12. Yü Tsung-Pên says that this term is from the *Chhi Min Yao Shu*, but it is not found in the *Chhi Min Yao Shu* as it exists today.

[f] Chhên Jung (4), pp. 213–14.

[g] *CSS*, p. 30.

[1] 俞宗本 [2] 種樹書 [3] 養餘月令 [4] 戴羲 [5] 醉竹日
[6] 毛竹

The Gardener says: 'Basically there is no secret to it, apart from these eight words: wide spacing, close spacing, shallow planting, deep planting.' This means plant them at a distance of three or four feet to allow space for the rhizomes to grow. Close spacing means that although they are planted far apart, four or five culms should be planted together so that a dense root structure will form. Shallow planting means that when they are planted, the trench should not be very deep. Deep planting means that although the trench is shallow, it should be filled with river mud.

The precautions to be taken in transplanting bamboos described in the *Chhün Fang Phu*[1], the *Shu Hsü Pu*[2], and the *Nung Chêng Chhüan Shu*[3], published at the end of the Ming dynasty (first half of the +17th century), are nearly identical. They advise keeping the mother culm and rhizome in the original sod while transporting it, cutting off leaves and branches to avoid wind damage, and they warn that the rhizomes should extend in the same direction when transplanted as they did in their original location.[a] A succinct summary of these precautions is given by Hsü Kuang-Chhi[4] in the *Nung Chêng Chhüan Shu*:[b]

When transplanting bamboo you should have a thick clod of earth [around the shoot]. This is what is called 'keeping a lot of the original sod' (*to liu su thu*[5]). Dig to a depth of about a foot in level ground, and place the clod inside it. Cover completely with loose soil. It is not necessary to tread or to hit the earth down hard. Water it every day, no more than you judge to be appropriate. You should also construct a [supporting] frame to prevent it being shaken by the wind. Another method is to cut the culm which you are transplanting four or five nodes above the first node with branching, so that it will not catch the wind. This is more convenient since it is not necessary to use a frame.

Bamboo is known for the rate at which it can grow, but if it is cut too early, it does not have the strength for which it is valued. When harvesting, some mature culms should also be left in the clump to give support and protection to new growth, and to maintain vigorous growth.[c] Harvesting is best carried out, then, in alternate years. The only time that bamboo is referred to as a wood product in the *Chhi Min Yao Shu* is when we are told that 'Bamboo should only be cut after at least a year has passed if it is to be used to make artefacts. If it is less than a year old, then it is soft and not yet formed.'[d] A more sophisticated system of planned harvesting which allows for recovery and regeneration between harvests is found by the Ming dynasty described in the *Chhün Fang Phu* and its contemporaries:[e]

[a] Contemporary manuals note that the rhizomes extend in the same direction underground as the first branches on the culm. This is helpful in deciding where to dig, but is not related to the direction in which the bamboo should be planted. Cf. Shang Yeh Pu Thu Chhan Tsa Phin Chü (1), *Mao Chu Ching Ying Chih Shih*[6], pp. 21–2.

[b] *NCCS*, ch. 39, p. 44a.

[c] Lessard and Chouinard (1), pp. 30–2.

[d] *CMYS*, ch. 51, p. 44a.

[e] *CFP, Li Pu*[7], p. 6a.

[1] 群芳譜 [2] 樹畜部 [3] 農政全書 [4] 徐光啓 [5] 多留宿土
[6] 毛竹經營知識 [7] 利部

With bamboo, 'the threes should stay and the fours should go'. That is to say, three-year-old [culms] should be left, and four-year-old [culms] should be removed. The proverb says 'the grandfather never sees the grandson, and the mother never leaves the son' which means that bamboo should be cut every other year.

Chhên Jung notes that the system in the proverb of cutting in alternate years is only appropriate to bamboos with pachymorphous rhizomes,[a] but in all other respects we can say that by the first half of the +17th century, the management of bamboo plantations had reached a level comparable to that which is practised today.

(ii) *Cunninghamia and intercropping*

Western naturalists and foresters surveying the devastation of China's forests by the end of the 19th century and the first half of the 20th century could see only one glimmer of light in the darkness:[b]

For these wild people have a crude system of forestry. It is largely based on religious superstition, as they think the wood gods become greatly angered by the cutting down of trees, and the way to appease them is to replant. Although this basis may be doubtful, it is a fact that a more or less clear cutting by groups and aiding natural regeneration by planting is practised; this being about the only case of forestry development in a country where on all sides forest destruction has been absolute.

The cultivation of cunninghamia, *sha mu*[1] (*Cunninghamia lanceolata* (Lamb) Hook) in the mountainous regions of Hu-Nan, Kuei-Chou, Chiang-Hsi, Fu-kien, and Kuang-Tung provinces has a long history.

The first point of interest is the important role played by ethnic minorities in cunninghamia forestry. Rosenbluth, in the preceding quotation, says that a superstitious fear of angering tree spirits is what caused the Miao[2] people to plant trees again after harvesting them. This is the only mention of such a belief, but most writers agree that the Miao, and the Yao[3] were particularly adept foresters[c] and a number of reports in the Chinese Journal of Forestry (*Chung Kuo Lin Yeh*[4]) immediately after the Revolution of 1949 report similar systems of cunninghamia management being practised by the Tung[5],[d] and of course by the Han themselves.[e]

We can only speculate on the origins of timber cultivation in these mountains, but the reason for the unusual preeminence of minority ethnic groups in forestry seems to be related to the history of the southward expansion of the Han Chinese. As settlement in the lowlands forced minority groups to move

[a] Chhên Jung (*4*), p. 208.
[b] Rosenbluth (1), p. 654. The 'wild people' referred to are the Miao people of Hu-Nan.
[c] See, for example, Shaw (1), pp. 57–9, and Fenzel (1), p. 63.
[d] Hsiao Phei-Lan (1).
[e] Kuang-Tung Shêng Lin Yeh Thing (*1*), pp. 32–6.

[1] 杉木 [2] 苗 [3] 瑤 [4] 中國林業 [5] 侗



Fig. 129. Swidden cultivation practised by the Miao in southern Hu-Nan. Hardwoods have been left to regenerate by sprouting, and cunninghamia has been planted in the fallow fields as a cash crop; photo Tshao Thie-Ju.

into the more remote mountainous areas the conditions were present and the players were in place for the following scenario to be played out.[a] The threat of erosion on the steep slopes made agriculture difficult and dangerous. Cunninghamia, which sprouts vigorously from the stump after fire, is one component of the original forest vegetation. The rugged topography of south China allows the transport of a bulky product like timber since there are more rapid rivers with a dependable flow of water than in the arid north. It would not take very long for the new migrants carrying out slash-and-burn cultivation on the hillsides, to devise a way of using the sprouts to grow timber for the developing urban markets of the Yangtse basin (Fig. 129).

We have already seen that there is evidence that cunninghamia was planted, apparently over large areas, during the Thang and Sung dynasties,[b] but it is not

[a] The most important movements of population followed the flight of the Sung court from Khai-Fêng[1] to Hangchow[2] in +1127. It is difficult to get an objective view of the migrations of the indigenous southern peoples since our sources are almost all written from a Han perspective, but an attempt to piece together the history of the Miao is found in Ruey (1).

[b] Cf. pp. 577–8, above.

[1] 開封 [2] 杭州

until the appearance of the *Nung Sang Chi Yao*[1], the Yüan dynasty Agricultural Encyclopaedia compiled in +1273 that we find a description of how to plant it:[a]

To plant cuttings of cunninghamia, choose the five days before and after 'the Day of the waking of the insects' (*ching chih jih*[2], the beginning of the third term of the solar calendar). Cut new branches. Dig a hole, put in a branch and pour in some mud, making it firm. Wait for a cloudy day to plant, and if it rains, then the cuttings will all survive. If there is no rain, then only a fraction of them will survive.

The same description is found again, quoted verbatim, in the *Wang Chên Nung Shu*[3] of +1313, and in the *Chung Shu Shu*[4] some years later.[b] The system described here of planting cuttings from new branches is not quite the same as the more usual practice found in later accounts, of selecting the most vigorous sprouts from a stump, cutting them, and then using them as planting stock. In both cases, though, the same word, *chha*[5], is used for planting.

For a full treatment of the selection of stump sprouts, we must turn to works of the latter half of the Ming dynasty, such as the *Chhün Fang Phu*[6] of c. +1621, or the *Nung Chêng Chhüan Shu*[7] of +1639. The latter work, which includes the comments of the author Hsü Kuang-Chhi[8] in addition to quotations from older treatises covers the subject in the most detail:[c]

Planting cunninghamia: In parts of Chiang-Nan such as Hsüan Shê[9] and Chhih Jao[10] where there are extensive mountains and rich soil, first plough the land and plant sesame for a year or more. Then at the beginning of the second month, when the pneuma (*chhi*[11]) are most abundant, cut fresh sprouts one foot and one or two inches in length. Use a dibble to make a hole and plant [the sprout] to a half of its length. Press the soil down firmly. Plant in rows about four or five feet apart. If they are closer, [the trees] will grow in height, if they are more widely spaced, they will grow in girth. Do not allow weeds and other vegetation. Weed and hoe every year. When they have grown to a height of three to four feet, then it is no longer necessary to hoe. If the mountain is suitable for growing crops, then plant millet in the summer and wheat in winter, which can replace weeding and hoeing.

The use of sprouts, and intercropping with agricultural crops are two characteristics of cunninghamia management that distinguish it from most conventional silvicultural systems. The rotation lengths were also longer than those we have encountered in the 'tree farming' systems of the agricultural manuals. We read in many local histories that cunninghamia was grown for about thirty years before the timber was sold and the plantation was clear cut, burned and regenerated from new sprouts.[d] There are accounts of timber harvesting in the

[a] *NSCY*, ch. 6, p. 10a.
[b] *WCNS*, ch. 10, p. 3a, and *CSS*, p. 37.
[c] *NCCS*, ch. 37, p. 36a.
[d] See, for example, the +1636 *Khai-Hua Hsien*[12] *Chih* in Chekiang province, ch. 3, p. 4a.

[1] 農桑輯要 [2] 驚蟄日 [3] 王禎農書 [4] 種樹書 [5] 插
[6] 群芳譜 [7] 農政全書 [8] 徐光啓 [9] 宣歙 [10] 池饒
[11] 氣 [12] 開華(縣)

forests, outside the agricultural context,[a] but they show no evidence of a concern for reforestation and sustained yield. The cunninghamia plantations were the first example in China of extensive rather than intensive forestry.

Forestry was the dominant form of land use on steep mountain slopes, but agriculture was not simply left to the lowlanders. Of particular interest today is the way in which forestry and agriculture were integrated into a system to which the modern label of 'agroforestry' is well suited. Details of land use found in contracts of tenure, in the local histories, in clan lineage records, and in anthropological descriptions reveal many different combinations of agricultural crops intercropped with trees. We have seen above that Hsü Kuang-Chhi recommended planting millet or wheat between the rows of trees until the canopy closed over. More recent reports mention vegetables planted with Cunninghamia[b] or the use of New World crops such as maize,[c] sweet potatoes,[d] and cassava.[e] Systems which applied the concept now known as ecological succession are also found. Crops with differing tolerance to shade were interplanted to suit the changing level of light as the tree canopy gradually closed overhead. Annual crops were followed by perennial crops, and finally by cunninghamia forest. The most commonly used perennial crops were (for *thung* oil, *thung yu*[1]) *Aleurites fordii*, the 'three-year *thung*', and *Aleurites montana*, the 'thousand-year *thung*', and (for tea oil, *chha yu*[2]) *Camellia oleosa*.

During the late Ming dynasty and the Chhing dynasty, the highlands of southern China were settled by a wave of landless migrants known as the 'shed people' (*phêng min*[3]) because of the flimsy construction of their temporary shelters. It is not yet clear what prompted them to leave the cultivated lowlands, but land scarcity has been cited as one possible factor.[f] Erosion and flooding were often the result of the slash-and-burn agriculture practised by these lowlanders unaccustomed to hillside conditions. The unsettled life style of the shed people and the damage caused by siltation and flooding to lowland agriculture concerned administrative officials in the affected areas. Local histories contain the texts of many memorials written on the subject.[g] The literature on the shed people gives us some information on agriculture and forestry in these remote areas. In some cases they became tenants, and we have some examples of contracts which show that tenants could be required to clear the land and plant cunninghamia and Masson's pine (*ma wei sung*[4]) a southern pine used mainly for fuelwood. In return for their labour, they could use the land to cultivate grain or cash crops until the trees matured, or they might be entitled to a share of the final crop of timber. A tenancy contract dated the 34th year of the Chhien-Lung period (+1780) includes a section which reads:[h]

[a] See (*d*), below, on 'Harvesting and Transport'.
[b] Chen Chi-Yun (1), p. 57.
[c] Lowdermilk & Li (1), p. 10.
[d] Fenzel (1), p. 92.
[e] Pendleton (1), p. 475.
[f] Fu (*2*), Morita (*1*), and Averill (1).
[g] See (*e*) (2), below, on soils and water.
[h] In Morita (*1*), p. 601.

[1] 桐油 [2] 茶油 [3] 棚民 [4] 馬尾松

... rental for the land, in addition to [the labour in] clearing the land, and planting out and maintaining cunninghamia, pines, tea [oil], and thung [oil], shall take the form of an agreement between the three parties that on such a day as the cunninghamia shall be deemed to have been grown to maturity, it shall be divided equally between the landowner and the tenant, the landlord taking five parts and the tenant taking five parts ...

During the 19th century, when Britain ruled Burma, the Colonial Administration in its attempts to develop teak plantations made use of a forestry system which allowed farmers to use plant food crops in land designated as teak plantations, on condition that they plant and care for teak seedlings in between the rows of food crops, and move on to another patch of land when the teak canopy closed over. The first plantation was said to have been grown by a Karen named U Pan Hle from the Tonze forests of Tharawaddy Division in northern Burma. U Pan Hle presented the plantation to Sir Dietrich Brandeis in 1856.[a] What became known as the taungya system (from the Burmese words *taung*, a hill, and *ya*, cultivation) proved succesful and was introduced to other colonies. Taungya is still used in many countries where land scarcity makes uneasy neighbours of forestry and agriculture. The similarities between taungya and the systems of cunninghamia management in neighbouring south China are surely more than coincidence. Cunninghamia and teak were both grown in mountainous regions for lowland markets. The minority peoples of the Burmese highlands and south China are ethnically related, and it is quite possible that taungya was simply an adaptation by British forestry officers of this traditional system of forest management.

The sustained yield of timber that became possible with cultivation from sprouts allowed some important changes to take place in the timber trade. We find, for example, that the market began to differentiate between timber from different sources, with trade names specific to logs from each region. Timber from Chiang-Hsi was called *hsi mu*[1], *chien mu*[2] came from Fukien, and so on.[b] The *Lung Chhüan* Assessment System (*Lung Chhüan Ma Chia*[3]) was devised as a universally accepted system of valuation in sales of cunninghamia. The timber trade acted as the medium through which the remote mountain valleys inhabited by ethnically distinct tribal people and by the shed people became linked to the developing economies of the great urban centres of the Yangtse basin.

(5) Tree Genies and Dragon Springs: the Story of Mensuration

Where timber is traded, all the parties involved in the commercial transaction need a mutually acceptable system of assessing volume and value if the market

[a] Blanford (1), p. 34, also see King, K. F. S. (1), p. 6.
[b] Chhên Jung (2), pp. 21–8.

[1] 西木 [2] 建木 [3] 龍泉碼價

is to operate smoothly. The first system of mensuration that went beyond very basic techniques of measurement and valuation of cut timber was the *Lung Chhüan* Assessment and Valuation System (*Lung Chhüan Ma Chia*[1]), which was devised specifically for use with cunninghamia logs in south China.

There is no evidence that growth rates were monitored, either in the tree farming systems of the agricultural treatises, or in the extensive commercial plantations of cunninghamia, but this is not to say that the Chinese were unaware of some of the basic principles of tree growth. In temperate climates, the rate of radial growth is measured from the width of each year's growth rings measured from a core of wood extracted from the tree.[a] The concept of ageing trees by tree rings is essential to this technique, but it is one which is difficult to trace in the written literature. Theophrastus is known to have remarked on the existence of tree rings, which he likened to the many layers of an onion,[b] but did not mention that these 'layers' represented annual growth. It was only in the Renaissance that Leonardo da Vinci and, some years later, Montaigne wrote of the annual nature of growth rings, and it was not until the second half of the +18th century that the idea was fully accepted by botanists.[c]

It may seem remarkable that what is now accepted without question was not recognised for such a long time, and it is of course possible that we are guilty of assuming general ignorance, when in fact Europe had to wait for the eclectic mind of a genius like da Vinci to put in writing what artisans and woodsmen had always known. The subject of tree rings is no more common in Chinese literature than it is in the West, but a ghost story[d] entitled 'The Cunninghamia Tree on Chhên's Tomb' (*Chhên Mu Sha Mu*[2]) by the Sung dynasty writer Hung Mai[3] shows that in the +12th century, it was common knowledge in China that one ring represents one year of tree growth. The story tells of a huge cunninghamia tree growing by the ancestral tomb of the Chhên family. The family decide to sell the tree to Wang I of the same village. The night before the tree is to be cut down, Chhên Phu has a dream in which several white-bearded old men appear with a warning:

> We have lived in this tree for three hundred and eighty years, and we are destined to be made into a coffin for Huang Chha-Yüan[4]. What makes you think you can cut us down whenever you feel like it?

The following day, a squabble breaks out about how to divide up payment for the tree, as a result of which the Chhên family lose both their property and

[a] This is not usually possible in the tropics. The rings are made visible by the difference between early and late annual growth. In the tropics, where there is little seasonal variation in growth rates, the rings are not necessarily correlated to annual growth. See Studhalter, Glock & Agerter (1) on the physiology of tree rings.

[b] In his 'Enquiry', quoted in Studhalter *et al.* (1), p. 10.

[c] Studhalter *et al.* (1), p. 17.

[d] *I Chien Chih, Ting Chih*[5], ch. 6, p. 585. I am indebted to Professor Chang Chün-Chhêng of the Peking Forestry University for bringing this story to my attention.

[1] 龍泉碼價 [2] 陳墓杉木 [3] 洪邁 [4] 黃察院 [5] 夷堅志。丁志

their fortune. Some years later, Tê Wan, son of Huang Chha-Yüan the recently deceased prefect of a nearby village, is searching for wood to make a coffin for his late father:

He made enquiries in his ancestral village, where he heard of the Chhên family cunninghamia. He was told, 'They wanted to sell it a long time ago, but because of a quarrel over forty cash, the different branches of the family have split up, and I am afraid they will not come to an agreement easily.' He sent someone to try to make the arrangements, and three days later the intermediary came back successful. By this time there were sixteen branches of the family, and they each received one thousand cash. Satisfied, they all came, and it was only when the tree had finally been felled to make a coffin that Phu told them about the dream he had once had. Wan examined the markings on the tree and found that there were indeed three hundred and eighty rings. 'The name of Chha-Yüan has found its resting place' he said.

Measurement and valuation of cut timber is encountered from the time of the earliest agricultural manuals. The requirements of the market mean that we can assume measurements were made for selling wood, but we have no record of what the units might have been. In the *Chhi Min Yao Shu*, the calculations of profits to be earned from elm, willow and poplar quote the value of timber by the cartload,[a] while oak, managed on a slightly longer rotation is priced by the log.[b] Later on, the price paid seems to have been based on a standard stacked volume agreed on between the seller and the purchaser, similar to the old European system of cords. The *San Shêng Pien Fang Pei Lan*[1], a 19th-century work by Yen Ju-Yü[2] on the border region between Shensi, Ho-Pei, and Ssu-Chhuan provinces says that different grades of timber were recognised, based on the size of the roundwood, and that the price for the stack was determined by the grade.[c]

Units of measurement used were not uniform for the whole country, nor indeed for any one region. A Japanese report on Chinese forestry and the timber trade published in 1940, at the beginning of the Sino-Japanese War, says that the timber markets of Peking used the Chinese foot, the British foot, the Japanese foot and the metric system. The Chinese foot itself was not standardised, with the *Min chhih*[3] from Fukien, the *Chiang chhih*[4] from Canton, the Peking Building Construction foot (*Pei-Ching ying tsao chhih*[5]), and the Board of Industry foot (*Kung pu chhih*[6]) all in current use.[d] The instrument used for shorter measurements was a flexible bamboo lath, marked in feet and inches, the *mieh*[7]. Trees were measured for circumference (*wei*[8]) at eyebrow height (*mei kao*[9]) which was defined as a height of five feet above any splitting or holes which

[a] *CMYS*, ch. 46.4, ch. 46.13, ch. 50.14.
[b] *Ibid.*, ch. 50.42.
[c] *San Shêng Pien Fang Pei Lan*, ch. 9, p. 2b.
[d] Yamauchi & Amano (*1*), pp. 146–51.

[1] 三省邊防備覽 [2] 嚴如煜 [3] 閩尺 [4] 江尺 [5] 北京營造尺
[6] 工部尺 [7] 蔑 [8] 圍 [9] 眉高

had been drilled in the base for raft construction when transporting the logs down river. Length was measured in paces (*pu*[1]) of three feet.[a]

The most highly developed system of volume measurement was used specifically for cunninghamia, and was known as the *Lung Chhüan* Assessment and Valuation, *Lung Chhüan Ma Chia*[2]. Sketchy details of the origins of the system have always been known, but it is only in the last thirty years that an attempt has been made to find reliable information on the subject.[b] Yang Fang-Hua has concluded that it was devised by the elder daughter by his second wife of Kuo Wei-Ching[3], of Lung-Chhüan county (Dragon Spring County), now Sui-Chhuan county[4], in Chiang-Hsi province. Kuo Wei-Ching was a *Chin-shih* scholar and a Ming loyalist who killed himself (+1646) when the troops he was leading were defeated by the Manchu armies.[c] Miss Kuo, as we must call her since there is sadly no record of her given name, was confined to the home with the other women of the family. She used sixty silken threads of different length and thickness to represent different grades and classes of cunninghamia timber, and to represent different stages of their growth. Consulting her father to verify her ideas in the field, she concluded that the relationship between size, measured by circumference and length, and volume changed in an arithmetical progression up to a certain age, after which the rate of volume increment becomes geometric. Based on this discovery she devised a set of tables by which the volume of timber large enough to be marketed commercially could be assessed by means of a calculation based on the circumference at eyebrow height and the length of the log.

The tables devised by Miss Kuo had eight categories (*ma-ming*[5]) which were further subdivided into a total of one hundred and twenty grades. The categories corresponded to an assessed value (*ma-chia*[6]), which was expressed as a monetary value in *liang*[7], taels or ounces of silver.[d] Each category was based on a range of values about a standard circumference, with a corresponding standard length. Variations within the range added or subtracted from the assessed value for that category, as did logs of less than the standard length. Further adjustment was made for deformities such as excessive taper, hollowness, rot, or knots.[e] The calculation ran as follows: a rate was negotiated for the monetary

[a] See Yao & Chang (*1*), pp. 100–4 for units of measurement used in the timber depots of south China.

[b] Chhên Jung (*2*), pp. 21–8, Huang (*1*), and Yang & Chien (*1*).

[c] Yang & Chien (*1*), p. 4. Yang says that he gleaned the story of the origins of *Lung Chhüan Ma Chia* in the Gazetteer of Sui Chhuan county (the only copy of which is in the county archives), and from interviews with Kuo Kuang-Yao[8], the eleventh-generation descendant of Kuo Wei-Ching. As both of these sources were unavailable to the author, the following account is drawn from Yang Fang-Hua's article.

[d] This was originally the actual price paid for the timber, but with changes in value of both silver and timber, the *liang* became a standard unit, the monetary value of which was negotiated between buyer and seller.

[e] Copies of the tables can be found in Chhên Jung (*2*), pp. 22–6, Huang (*1*), p. 192, and Yang & Chien (*1*), pp. 11–15.

[1] 步 [2] 龍泉碼價 [3] 郭維經 [4] 遂川 [5] 碼名
[6] 碼價 [7] 兩 [8] 郭光耀

value of a *liang* (tael). Circumference and length of the log were measured to find the assessed value. A log of 2.5 feet in circumference, for example, was in the *ta chhien ma*[1] category whose standard circumference was 2.25 feet, with a standard length of 46 feet, and whose assessed value was 0.405 taels. Adjusting for the extra circumference, the tables give an assessed value of 0.530 taels. If the log in question had several large knots, a downward adjustment of two inches would be made, giving a final assessed value of 0.430 taels.

The exact values in the tables, and the practical details of measurement varied with the specific requirements of different areas and different markets for cunninghamia, but were never adapted for use with other species which continued to be sold by the cord or by the log. The development of a management system for cunninghamia which produced a sustained yield of timber to satisfy the growing urban markets made an objective system of valuation imperative. The *Lung Chhüan* Assessment and Valuation system was a response to this need, and Miss Kuo's achievement ranks high in the history of forestry. The tables she devised with the help of her father appeared and were widely adopted almost exactly a century before the publication in +1736 of the tables developed in England by Edward Hoppus, which were used by British foresters until the introduction of the metric system.[a]

(*d*) HARVESTING AND TRANSPORT

(1) HARVESTING

The final stage of forest management is the harvest of mature trees and the transport of timber out of the forest or plantation. The bulk and weight of logs are the main problems to be resolved in designing systems of harvesting and transport, problems which were exacerbated when the forests were located in remote mountain areas, with steep slopes and difficult access routes. Lowdermilk noted in 1926[b] that the costs of transporting timber from the forest to the point of sale were so high that only the most valuable material was actually removed from the site of harvesting, leading to extremely wasteful practices. He estimated that 'fully 15–25 per cent of the volume of trees is left in high stumps, and waste tops. More valuable timber is being wasted here [in the Lu Ya Shan[2] area of Shan-Hsi] than is being grown in plantations near the plains.' Efficient harvesting and transport systems play a part in forest management by ensuring that timber is not lost to wastage and rotting before it can be used, and by minimising ecological disturbance at the site of harvesting, allowing rapid regeneration to take place, either naturally or through human intervention.

[a] The *Lung Chhüan* system was used in China until the early 1950s when it was replaced by the metric system.

[b] Lowdermilk (*4*), p. 129.

[1] 大錢碼 [2] 蘆芽山

The question of the timing of timber harvest was an issue addressed both in administrative codes such as the *Chou Li*, and in specialised treatises on agriculture.[a] The 'timing of harvest' refers to timing within the annual cycle of agricultural activity, and to the length of a rotation, or the age at which the tree is to be cut. Early writers who recommended that the season for cutting timber should be determined in accordance with the principles of Yin and Yang sought to ensure successful regeneration following harvesting.[b] The authors of the *Chhi Min Yao Shu* and later agricultural treatises also hoped to avoid waste and the loss of timber by cutting trees at a time of year when the felled logs would be at the least risk from insects and rot. This was also a subject of concern to writers in ancient Europe. Theophrastus discussed the timing of harvest, but his main concern seemed to have been the presumed difference in strength between wood cut in spring, when the sapwood is wet, and timber cut at the end of the summer or in autumn. He noted that oak rots very quickly when it is cut too early in the year, and therefore recommends late harvesting.[c] If the many different dates proposed in the agricultural manuals for logging seem inconsistent,[d] it is well to remember that the authors were addressing the problems of regeneration and of wood preservation at the same time.

The technology of harvesting timber remained essentially the same throughout the world from the introduction of metal axes and later of the saw, until the recent advent of machinery such as the chainsaw which has transformed the pace of tree felling, and thus the area of forest which can be cut in one operation. A poem in the *Book of Odes* gives vivid pictures of trees being felled, and the onomatopaeia in the first line tells us that the loggers are working with axes.[e] Where trees were grown on agricultural estates, the small diameters being cut due to short rotations, combined with ease of access made timber cutting a routine task, and the subject need not concern us here. Of more interest are the logistical problems which had to be resolved in cutting large old growth trees in remote natural forest areas.

Chinese poets delighted in the wonders of nature, but they wrote of rural landscapes where mountains and trees formed a restful backdrop to the contemplations of the artist, while truly untrammelled nature filled them with dread as we see in Li Po (+701 to +762)'s famous lines on the hardships of the 'Road to Shu':[f]

[a] See pp. 609–11, above.

[b] See pp. 611–612, above.

[c] Theophrastus, '*De Causarum*', cited in Studhalter *et al.* (1). There is actually no evidence that this is true.

[d] The *Chou Kuan*[1], for example, says that Yin trees should be cut in midsummer, while the *Yüeh Ling*[2] section of the *Li Chi*[3] specifically prohibits cutting at the height of summer. Quoted in *Chhi Min Yao Shu, Fa Mu*[4], ch. 55·3 and 55·4, p. 317.

[e] *Shih Ching, Wei Fêng*[5], *Fa Than*[6], Karlgren (14), no. 112, p. 71.

[f] *Shu Tao Nan*[7]. Transl. Waley (13), p. 40. See Fischer (1), for a discussion on trees and forests in Chinese art and literature. Also, Tuan (1).

[1] 周官 [2] 月令 [3] 禮記 [4] 伐木 [5] 魏風
[6] 伐檀 [7] 蜀道難

It would be easier to climb to Heaven
than walk the Szechwan Road,
And those who hear the tale of it
turn pale with fear.
Between the hilltops and the sky
there is not a cubit's space;
Withered pines hang leaning over precipitous walls.
Flying waterfalls and rolling torrents blend their din,
Pounding the cliffs and circling the rocks
they thunder in a thousand valleys.
Alas, traveller, why did you come to so fearful a place?

In the first half of the +17th century, Hsieh Chao-Chê[1] wrote of the horrors faced by labourers sent into the forest to cut the wood required to rebuild the Imperial palaces in Peking:[a]

I have seen men who have been to cut Imperial timber. They say that there, in the depths of the mountains and in the empty valleys, where no man has been before, there are trees from the [ancient] days of wilderness and chaos. But it is wild and rank and extremely dangerous. Poisonous snakes and bloodthirsty animals move in and out of the mountains. There are spiders the size of cartwheels whose webs hang down to the ground like nets to trap tigers and leopards which they eat.

(2) TRANSPORT

In view of the difficulties of moving timber out of the forest it might seem desirable to carry out at least the initial stages of processing before transporting it to market. Sawmills were not, however, located in the forest. This may be due to the 'cut and run' nature of most logging operations precluding the commitment of funds and labour required even for a simple structure like a pit-saw. This stands in contrast to traditional Japanese forestry, in which logs were squared before being made up into rafts and floated down the river.[b] The mid-19th-century work, *San Shêng Pien Fang Pei Lan*[2] by Yen Ju-Yü[3] says that *Fang Pan*[4], 'Dressed Planks', one of the three grades of timber produced in the mountains between Shan-Hsi, Ssu-Chhuan and Ho-Pei were sawn by hand into planks before being carried down the mountain,[c] but the sawmills (*mu chhang*[5]) were located at some distance from the forest. This is confirmed by photographs published by Lowdermilk and E. H. Wilson of planks being carried down mountain trails,[d] but it seems to have been the exception rather than the rule (Fig. 130).

[a] *Wu Tsa Tsu*[6], ch. 10, p. 12a.

[b] The process is shown clearly in sections 7–9 of the 19th-century scroll painting 'The Wood-cutting and Transporting System of Kiso Style'. In his study of the scroll, Tokoro Mitsuo suggests that in Japan it was cheaper to carry out this initial processing in the forest than in a sawmill. Tokoro (1), p. xi.

[c] *San Shêng Pien Fang Pei Lan*, ch. 9, p. 2b.

[d] Lowdermilk (4), p. 130, and Wilson (3), vol. II, opposite p. 22.

[1] 謝肇淛 [2] 三省邊防備覽 [3] 嚴如煜 [4] 枋板 [5] 木廠
[6] 五雜俎

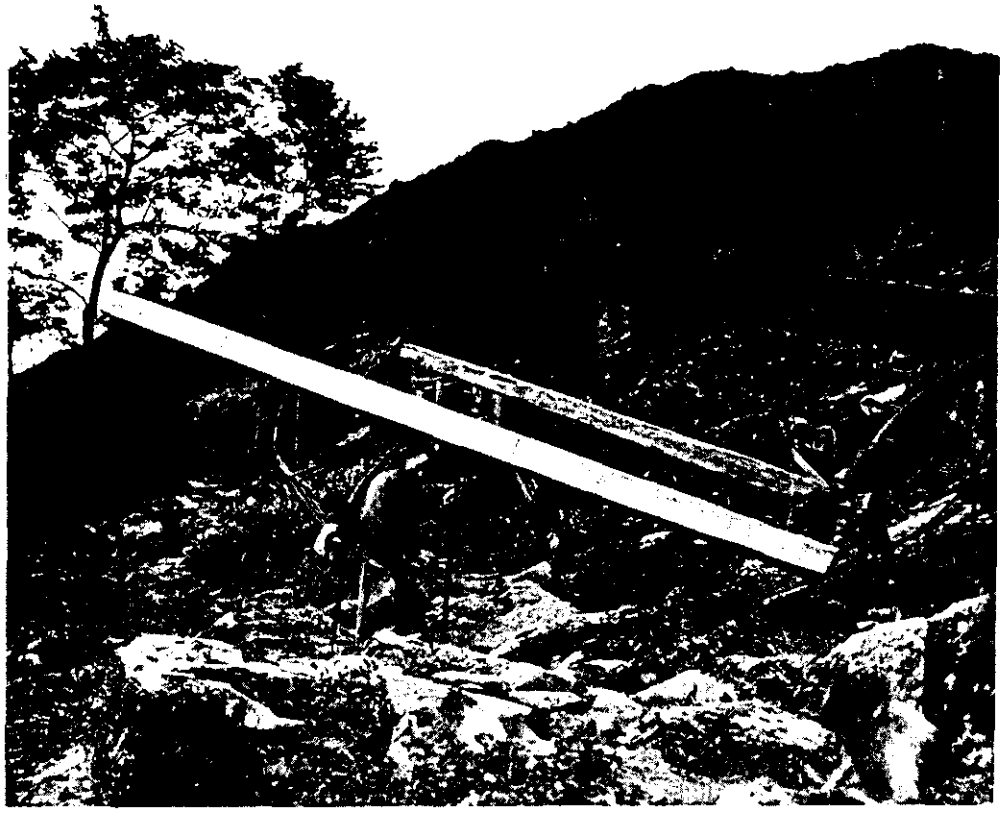


Fig. 130. Carrying dressed planks from logged areas in the hills; from Wilson (3), vol. 2, opposite p. 212.

The use of porters to carry timber out of the forest was common. Several sources describe the terrible hardships that timber porters endured in the transport of large timber. During the Ming dynasty, construction of the Imperial palaces in Peking required a tremendous quantity of wood, which was procured from all parts of the Empire. A +17th-century artist was moved to paint a scroll entitled *An Yün Thu Shuo*[1]. 'The Procurement and Transport [of Timber] Illustrated and Explained' depicting the sufferings of these labourers in the hope that the authorities would reduce their demand for timber.[a] In +1598, the Ming official Lü Khun[2] wrote a memorial in which he suggested that the extravagant demands for timber were one cause of the discontent which threatened to erupt into open rebellion:[b]

Now when a tree is first felled, a thousand men have trouble moving it, and if they encounter any obstacle, some of them will certainly be injured. There is a saying in

[a] The scroll, now lost, is mentioned in the *Chhun Ming Mêng Yu Lu*[3] by Sun Chhêng-Tsê[4], ch. 46, pp. 61b–64a. Quoted in Yang (11), p. 38.

[b] *Ming Shih*[5], ch. 226, p. 5938.

[1] 按運圖說 [2] 呂坤 [3] 春明夢餘錄 [4] 孫承澤 [5] 明史

Shu[1] [Ssu-Chhuan] that 'one thousand men go into the mountains, and only five hundred come out', which gives some idea [of their suffering].

The fullest account of logging and transportation in north China is in the *San Shêng Pien Fang Pei Lan* which says that the task could be alleviated to some extent by waiting until winter when the larger logs could be moved over ice and snow. Yen Ju-Yü also notes that especially valuable timber is carried by porters to avoid damage which might occur if it were rafted downstream:[a]

Yu pine (*yu sung*[2]) (*Pinus tabulaeformis*) is the best wood for planks (*fang pan*[3]). In mountainous areas with many termites, *yu* pine is the most favoured timber for making coffins, and it can fetch a price of up to a hundred gold coins or several tens of gold coins. It must not be transported by water, but should always be carried by porters. These porters, who carry [the timber] on their backs are exceptionally strong. I estimate that one plank must weigh about two or three hundred catties. The loggers on the slopes give them the nickname of 'mules', and they are really just about [as strong as] mules, but they cannot travel far. They cannot go much farther than thirty or forty *li* in a day. They do not rest in inns, but they carry their own copper cooking pots and dry rations. They form convoys and spend the night in caves or under the trees.

(i) *The engineers' solutions*

Hofman, in 1914, saw logs being moved on slipways built on trestles in rough terrain (Fig. 131) in Japan,[b] and similar structures were reported from Kuei-Chou by Shaw at about the same time.[c] The photograph in Hofman's book looks remarkably similar to photographs of logging in America's Pacific Northwest only a few decades earlier, but there can be no doubt that the technology was indigenous to China. The biography of Chang Chung-Yen[4] in the *History of the Chin*[5] *Dynasty* records that at the beginning of the Huang-Thung[6] reign period (+1141), Chang was charged with the transport of timber to Khai-Fêng[7]:[d]

Large timber was most abundant in the Chhing Fêng Mountains, but they were so rugged and precipitous that it had been impossible to get to [the timber] since the Thang and the Sung dynasties. Chung-Yen spanned the precipices and yoked the ravines (*kou ya chia ho*[8]) by building a bridge over ten *li* in length. Vehicles transported the timber as easily as if it had been on flat ground.

The most detailed description of one of these trestle slipways comes, once again, in the *San Shêng Pien Fang Pei Lan*. The costs which must have been involved in building these structures are a good indication of the value of high-quality timber once it finally reached the markets in the lowlands:[e]

[a] *San Shêng Pien Fang Pei Lan*, ch. 9, p. 4b
[b] Hofman (1), opposite p. 146, pl. 58.
[c] Shaw (1), p. 96.
[d] *Chin Shih*, ch. 17, p. 1789.
[e] *San Shêng Pien Fang Pei Lan*, ch. 9, p. 2a. See Vol. 4, pt 3, pp. 20–2 on 'hanging gallery' roads.

[1] 屬 [2] 油松 [3] 枋板 [4] 張中彥 [5] 金
[6] 皇統 [7] 開封 [8] 構崖駕壑



Fig. 131. Trestles for transporting logs out of the forest. The photograph was taken shortly before the First World War in Kiso, Japan, but the structures are similar to those described by Yen Ju-Yü in the early 19th century, in the Chhin-Ling mountains; from Hofman (1), opposite p. 146.

In Chouchih county[1], Shensi province, there are places such as Huang Po Yüan[2], Fo Yeh Phing[3], and Thai Pai Ho[4] where the large mills have already logged two hundred *li* or more into the old growth forest, and it is now necessary to build slipways (*liu tzu*[5]) [to transport the logs]. Small logs are cut into lengths of about ten feet, with sleepers across them, laid out to produce a smooth surface rather like the plank construction of a shop. It is about seven or eight feet wide, and the logs are placed in a continuous line with the front of one touching the back of the next one. The topography in these mountain valleys rises and falls unevenly. Where it rises, an embankment is built of stone, and where there are depressions, wooden pilings are driven in with sleepers laid across them to maintain a level surface. Slipways are built everywhere, even along valleys several tens of *li* in length, leading to the water. They are built in the same way as the hanging galleries (*chan ko*[6]), and they look like bridges. Their construction is one of the most costly operations for a timber mill in terms of labour and timber.

On the very steepest slopes, where even slipways were impossible to build, Yen Ju-Yü says that logs could be carried by a cable system which he calls a crane, *thien chhê*[7]. This is the only reference I have encountered to cable yarding, so it is difficult to say whether it had been in common use for a long time, or whether it was considered very new and unique to the mountains of this bor-

[1] 盩厔 [2] 黃柏園 [3] 佛爺坪 [4] 太白河 [5] 溜子
[6] 棧閣 [7] 天車

der region. The capstan device is of course not peculiar to forestry and could well have been adapted from marine technology:[a]

Logging operations are usually carried out in mountain valleys, where peaks and ridges must be crossed, and where it is difficult to deploy labourers, making it necessary to use a crane (*thien chhê*[1]). They dig out a landing on the ridge of the mountain. They then select two wooden poles and hang a cross beam between them on which they attach an octagonal wheel. A rope is slung from the wheel which turns with it. A few paces away where the poles have been set, the ground is dug out until it is fairly level and they prepare a capstan by setting up one pole as an axle on which another octagonal wheel rotates horizontally. Eight stakes are attached, one to each corner of the wheel. They use a strong leather rope which is passed around the crane. One end of the rope is tied to an iron eye attached to the log. Two oxen or four or five mules are used. If they have no oxen or mules, then twenty or thirty men turn the capstan like a stone mill. The rope winds around the stakes on the corners of the wheel, bringing the log up with the rope. The capstan wheel is seven or eight feet in diameter and six or seven feet high, and the rope cannot be longer than three thousand feet (three hundred *chang*). Up to four sets of these machines can be set up depending on the topography of the mountain, and they are called cranes. This uses more labour than any other timber operation.

(ii) *Rafting and water transport*

In spite of the technological interest of these engineers' solutions to the problem of transporting timber, the most important method of transport always was, and still is, to form rafts (*fa*[2]) of logs and float them downriver. Felled logs are assembled as close to the logging site as possible. The tapered tops are bunched together and tied to form a triangular-shaped raft, which is given some rigidity by tying the logs with bamboo hawsers. In some cases the hawsers were passed through holes drilled at the base of the logs although this meant some loss in value, since length was assessed from 'eyebrow height' five feet above any damage or holes in the butt of the log.[b] As the rafts travelled downstream and entered the major river systems, they would be joined together to form huge floating platforms, on which the raft hands built shelters to live in and even kept pigs or grew vegetables.[c] Travellers who saw these rafts were all impressed by their size and construction, even when they themselves came from an important timber producing region as did Robert Dollar, a timber magnate from California who wrote in 1921:[d]

[a] *San Shêng Pien Fang Pei Lan*, ch. 9, p. 2b.

[b] These drilled logs were known in the lumber yards of Su-Chou[3] as 'elephant trunks' *hsiang pi*[4]. In Yao & Chang (1), p. 102.

[c] Shaw (1), pp. 57–9. Shaw also explains that the timber had been bought by guilds based in the cities who had an effective monopoly of the trade in cunninghamia from Hu-Nan and Kuei-Chou.

[d] Dollar (1), p. 72.

[1] 天車 [2] 筏 [3] 蘇州 [4] 象鼻

On the way up the river, near Wuhu, we passed four rafts of poles that had been brought from a considerable distance up the river ... The rafts were over one hundred feet wide and about four hundred feet long, and as they were six feet out of the water they must have been eight feet under, making a mass fourteen feet deep. Most of the surfaces of the rafts were covered with mat houses for the crew of considerably more than one hundred men to each raft ...

In my younger days I had considerable experience in rafting timber, but I have never seen anything that approaches the mass of timber in one of these rafts, which must have taken considerable skill to bind together. In a swift water I must confess that without anchors, I would not know how to do it.

The technical simplicity of rafting, which requires little or no capital investment explains its world-wide popularity wherever timber is located in mountainous areas a long way from processing facilities and markets. While descriptions of logging in China, where they exist, focus on the terrors and hardships of the loggers sent into the unknown darkness of the forest, rafting seems to have captured the imagination of some writers, and even of a few painters. Confucius made use of the metaphor of the raft in the Analects.[a] One of the very few objects relating directly to forestry to have been excavated by archaeologists is a decorated brick from Ssu-Chhuan dating from the Han dynasty. The scene on this brick shows the poles bunched together at the tapered end, forming a raft of almost identical construction to those used today (Fig. 132). To emphasise the continuity of this style of raft, there is a +13th-century Yüan dynasty painting in the Peking Museum of History, 'Rafting Timber at Lu Kou' (*Lu Kou Yün Fa Thu*[1]) which shows timber being brought to a depot at the Marco Polo Bridge (*Lu Kou Chhiao*[2]). The architectural details of the bridge, one of Peking's foremost tourist attractions today, are recognisable, suggesting that we can trust to the accuracy of the artist's rendering of the scene (Fig. 133). The painting shows rafts, of the familiar triangular shape, being floated down from the hills in the background, to be broken up for sale downstream of the bridge, and transported by cart to the city.[b]

Where gradients are steep, or water flows irregular, streams were modified to improve conditions for rafting logs out of the forests. Timber must already have been of great economic importance in Ssu-Chhuan at the beginning of the Chhin dynasty. The *Hua Yang Kuo Chih*[3] ('Records of the Country South of Mount Hua'), an historical geography of south China of +347, records that in the year −231, during construction of the great water conservancy project at Tu Chiang Yen[4], south of Chhêng-Tu[5] in Ssu-Chhuan, some of the channels were designed to allow the transport of rafts of catalpa, cypress, and bamboo to the

[a] *Lun Yü* 5, *Kung Yeh Chang*[6] 6. Legge (*2*), p. 174.

[b] See Lo Chê-Wên (*3*), for a detailed description of the painting and some speculations as to its origins.

[1] 蘆溝運筏圖 [2] 蘆溝橋 [3] 華陽國志 [4] 都江堰 [5] 成都
[6] 公冶長

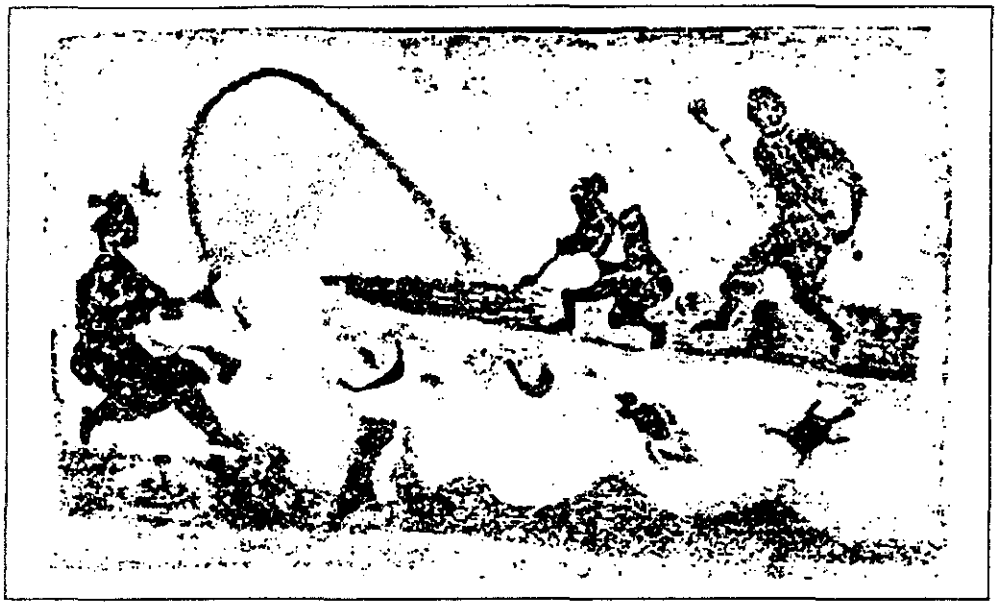


Fig. 132. A rubbing from a Han dynasty brick showing timber being rafted down a river in Ssu-Chhuan. The raft is assembled by tying logs together at one end, resulting in a characteristic triangular shape still seen today; from Liu Chi-Yüan *et al.*, p. 32.

city.[a] An alternative to physical modification of the stream bed is found in the *San Shêng Pien Fang Pei Lan*[1] which says that in the more arid mountains of the northwest, logs were assembled in the dry river beds during the winter, and then floated down with the floodwaters following the spring snow melt.[b]

Water may seem to be the most abundant renewable natural resource, yet it is possibly the cause of more conflict than any other resource. Diversions of water which are beneficial to upstream users, can have a drastic effect on downstream users. On the same stretch of a river or canal, there may be conflict as different groups of users make different demands on the flow of water.[c] The *Ssu Ming Tho Shan Shui Li Pei Lan*[2], a work on canals and irrigation by the Sung dynasty hydraulic engineer Wei Hsien[3] of 1242, complains that timber rafts were so big and unwieldy that they were damaging the dykes of the irrigation system serving the area around present-day Ning-Po.[d] Control of water flow could be bitterly contested between commercial timber dealers and the inhabitants of the valleys along which the logs were rafted as we read in this entry in the local history of Chiang Hua county[4] in Hu-Nan, dated 1870, but which is a re-edition of an earlier work compiled in +1769:[e]

[a] *Hua Yang Kuo Chih*, ch. 3, p. 30. For this project see Vol. 4, pt 3, pp. 289ff.
[b] *San Shêng Pien Fang Pei Lan*, ch. 9, p. 4a.
[c] See (*e*) (2), below.
[d] *Ssu Ming Tho Shan Shui Li Pei Lan*, ch. 1, p. 13b.
[e] *Chiang-Hua Hsien Chih*, ch. 10, p. 16b.

[1] 三省邊防備覽 [2] 四明它山水利備覽 [3] 魏峴 [4] 江華縣

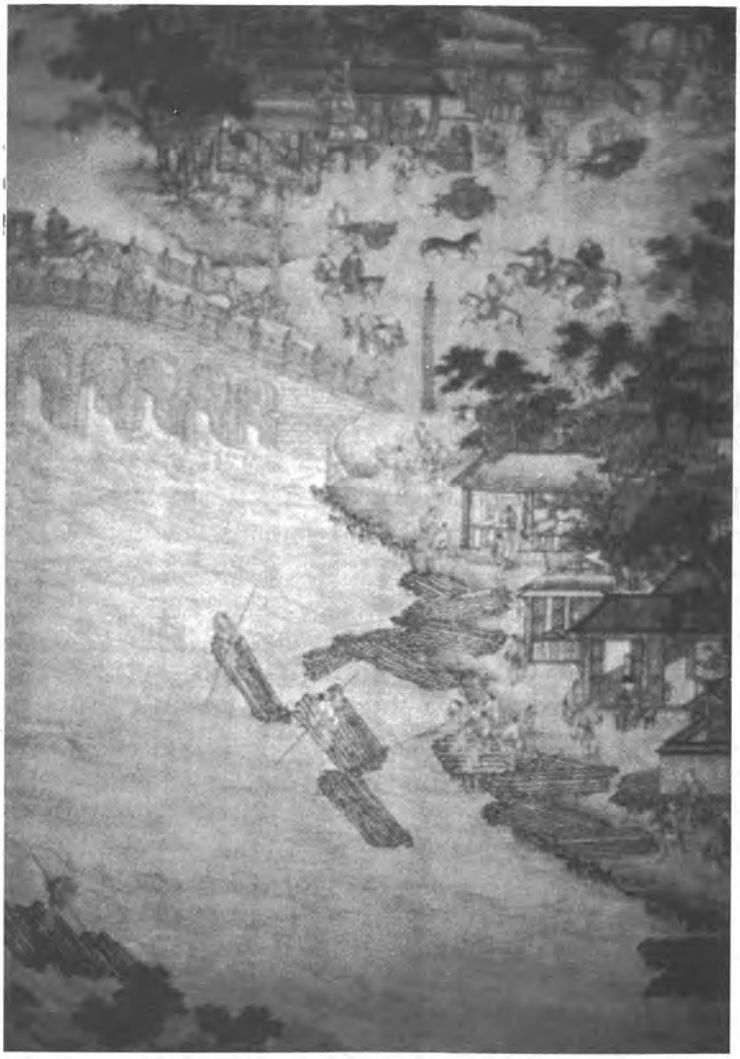


Fig. 133. Log rafts arriving at a depot near Peking. The bridge above the depot in this Yüan dynasty painting is recognisable as the 'Marco Polo Bridge' west of the capital; painting in the Collection of the Museum of Chinese History, photo by N. K. Menzies.

Timber dealers assemble rafts [of logs] to sell in the south and in the east. During autumn and winter the river runs low, and their passage is blocked by dams. Whenever the timber merchants come across one where there is no one [on guard], they break the dam to gain passage. The peasants are therefore always upset by their passage, and are infuriated that they should destroy the dams. They demand payment before they will let them go. This is called the 'dam tax'.

It is interesting to note that the social and economic changes which occurred during the late Imperial period were not confined to the cities, but had important repercussions in the rural hinterland. The timber trade, and especially the

commercial production and sale of cunninghamia logs, was a powerful force linking remote regions, populated by ethnic minorities, to the growing urban centres of the Yangtse region. The natural communications provided by the rivers ensured that these mountain valleys would never be completely isolated from events in the outside world.

(*e*) PREMONITIONS OF ECOLOGY

(1) FOREST INFLUENCES

Agriculture produces valuable crops on relatively small tracts of land. High expenditures of energy can be justified, and it is common to modify the original ecosystem by ploughing and levelling, by irrigation and by replacing the diversity of the native plant community with a monoculture. In forestry, a crop of relatively low economic value is produced after the passage of many years. It is spatially extensive, with high costs of harvesting and transport. Unless species of exceptional value are grown very close to markets, high expenditures to alter environmental conditions cannot be justified. It is essential, instead, to manage within the constraints of the natural ecosystem and to use the species already present at the site.

Agricultural ecosystems are structurally simple, usually consisting of only one species. Energy flows are concentrated on primary production, and considerable inputs of cultural energy are required in the form of human labour and fertilisers in order to maintain what is in effect an ecosystem in a state of arrested succession.[a] Forest ecosystems are structurally complex. There are more ecological niches to be filled by different species of plants and by other life forms such as fungi or wildlife, which may be valuable forest products in their own right.[b] The information needed to manipulate these systems is complex, and must rely on our understanding of the relationships between and within species, knowledge which is now classified as the science of ecology.

The concept of the ecosystem has proved to be a useful analytical tool in forestry during the last century. Ecology offered insights which were easily translated into improved techniques for management. The concepts of the interaction of biotic and abiotic components, for example, or of inter-species relationships within the ecosystem, have led land managers to consider the use of fire and grazing as tools to achieve the desired mix of species in a forest. It would be vain to look for immediate equivalents of modern ecological theory in the early Chinese literature on forestry, but there are strains of thought in Chinese cosmology which show premonitions of ideas such as adaptation, the interdepen-

[a] Cox & Aitkens (1), chapter 24.

[b] At times, wildlife and other forest products have been of more importance than the trees. One of the earliest definitions of a forest in English is found in the '*Dialogus de Saccaro*' of Richard fitz Nigel, c. +1179: 'the king's forest is a safe refuge for wild beasts; not every kind of beast, but those that live in woods; not in any kind of place, but in selected spots, suitable for the purpose' in James (1), p. 4.

dance of different components of the ecosystem, and forest influences on soil stability, water flow, and microclimates.

(i) *From cosmology to autecology*

Chinese scholars and scientists used the dominant cosmology of *Yin Yang*[1] and *Wu Hsing*[2], the two forces and the five phases or elements of nature, to develop a framework for their understanding of natural phenomena. The formulation of this cosmological system is attributed to Tsou Yen[3] (−350 to −270), of the State of Chhi[4], on the basis of what had first emerged as two separate concepts. Tsou Yen conceived of a Universe whose operation rested on the two complementary forces of Yin and Yang, related to observed complementary qualities or properties in nature such as male and female, light and dark, hardness and softness. The two forces moved and operated in a cycle of five phases, symbolised by the five elements of metal, wood, water, fire and earth, in a sequence in which one element followed the other. From this basic scheme, Tsou Yen and later philosophers devised a complex pattern of correlations between earthly phenomena and the unalterable way of Heaven. The *Yin Yang Wu Hsing* system was particularly influential during the Han dynasty, but concepts such as Yin and Yang remained fundamental to Chinese thought throughout the pre-modern era.[a]

For wood to have entered the cosmological system as one of the elements, it must have been recognised as possessing unique qualities setting it apart from other substances in nature.[b] Although it is unlikely to date from before the Warring States period, the 'Grand Norm' (*Hung Fan*[5]) chapter of the *Shu Ching* is said to be the first exposition of the theory of the *Wu Hsing*. The essential property of wood is said to be that it is 'crooked and straight',[c] which may not sound very impressive for one of the fundamental elements of nature, but simple as they may seem, these are properties which make wood one of nature's most versatile construction materials.

In the 'Grand Norm' chapter, we also find ideas which developed into concepts we would now call autecology and ecosystemology. The chapter contains the prescriptions for virtuous and harmonious rule of Chi Tzu[6], a minister of the last ruler of Shang. His discourse begins by referring to an earlier period of disorder caused, he says, when Kun[7] dammed up the floodwaters (instead of channelling them as his successor Yü did) 'and thereby threw into disorder the

[a] For a full study of Tsou Yen's system, see Vol. 2, pp. 232–302.

[b] Ursula Franklin, John Berthrong and Alan Chan have made the point that inclusion of metal into the cosmological system implies a long process of generation and transmission of knowledge of metallurgy. See Franklin, Berthrong & Chan (1).

[c] *Shu Ching, Hung Fan*, Transl. Legge (1), 5.4.4, p. 324.

[1] 陰陽 [2] 五行 [3] 騶衍 [4] 齊 [5] 洪範
[6] 箕子 [7] 鯀

five elements'.[a] When Yü took over the task of flood control, harmony was restored between the five elements, and order reigned. The germ of ecological concepts is found in this need to keep the five elements in harmony. All the elements are important components in any ecosystem. Metal (in the form of soil nutrients), water, earth (or soil), fire and wood (or vegetation) are factors which determine the functioning of the system, and changes in any one of them will have consequences for the whole system. To seek order by maintaining harmony among the five elements could be paraphrased in contemporary terminology as 'maintaining ecological equilibrium through environmental protection'.

Seasonal changes in foliage and growth of trees were closely observed by the writers of agricultural and botanical treatises, and they were readily associated with the concept of Yin and Yang. We have already discussed the implications of Yin and Yang as they affected the timing of timber harvest, and as they came to be used in the way we now use the terms shade tolerant or intolerant. The concept was easily applied to forestry, but the commentators of the *Chou Li* were unable to agree on just what was meant by a Yin tree or a Yang tree.[b]

In addition to the metaphysical concepts of complementary forces and the five phases, we find reference to *chhi*[1], a term familiar from its use in other fields of science such as alchemy and medicine, and sometimes rendered as the 'pneumas of the earth'. Applied to tree cultivation it seems to have had two meanings. The first is in the sense of an essential fluid carrying with it the breath of life. The *chhi* was said to originate in the earth, and was made manifest as life-giving fluids within the plant, a possible reference to sap. The flow of *chhi* varied with the seasons, so silvicultural activities were often timed with respect to the flux of the pneuma.[c] We read of potted pines and junipers, with a limited supply of soil, requiring special attention if they are to have enough *chhi* to flourish:[d]

> If pines and junipers are cultivated in pots, then the pneuma of the soil are shallow and thin. It is necessary to remove the original earth from the roots every year [to replace it with new soil].

An alternative interpretation of *chhi* is found in the same work, the *Chhün Fang Phu*, quoting from the *Po Wu Chih* attributed to Chang Hua[2] (c. +290):[e]

> The *Po Wu Chih*[3] says that pines take root from the pneuma of rocks. The rock splits, some sand accumulates, and it brings forth a pine tree. After three thousand years, the pine is transformed back into rock. The many pine trees on Mount Thai[4] are derived from its rocks.

[a] *Ibid.*, Transl. Legge (1), 5.4.3, p. 323.
[b] Cf. pp. 609–10, above. Also see Kan To *et al.* (1), p. 255, for a summary of the different applications of the theory of Yin and Yang to forestry.
[c] See the instructions for planting cunninghamia in *NCCS*, ch. 37, p. 36a. Transl. p. 628, above.
[d] *CFP, Mu Phu*[5], *Shou Chien*[6], p. 9a.
[e] *CFP, Mu Phu*, ch. 2, p. 7b. This extract also shows an understanding of the process of soil formation.

[1] 氣 [2] 張華 [3] 博物志 [4] 泰(山) [5] 木譜
[6] 首箭

Chang Hua suggests here that the natural and physical characteristics of any locality are determined by its pneuma, so the pines of Mount Thai could only have originated in the *chhi* peculiar to that rocky peak. In this sense, *chhi* is closer to what Schafer calls 'energetic emanations of local soil topography the active principles of what we now call biomes'.[a] As with the principles of Yin and Yang, the concept of *chhi* gave some insight into the environment, but there was no consensus on how it functioned.

Harmony among the five elements was needed to maintain order in the natural world, but how was harmony to be achieved? This question was best answered by the quietist stream of Chinese philosophy, which held that human endeavour could only succeed by respecting the 'Way', (the *Tao*[1]), and its principles.[b] 'It gives height to the mountain and depth to the abyss, it fashioned beasts to walk and birds to fly' said the *Huai Nan Tzu* of the Tao[c] drawing a direct link between the great guiding principle of the universe and earthly phenomena. Later authors also advocated following *Thien*[2], or Heaven, meaning what Heaven has ordained, saying that by conforming to *Thien*, it was possible to reach the essential nature of its creatures, and so to succeed in nurturing – or cultivating them. The secret of success for Camel Kuo Tho[3] the tree planter in Liu Tsung-Yüan's[4] parable was to respect what Heaven had ordained, and not to force the seedlings, or to plant them in ground unsuited to their nature.[d] In +1621, Wang Hsiang-Chin[5] related respect for Heaven and the nature of plants to the distribution of species in his introductory words to the section on trees in the *Chhün Fang Phu*:[e]

> The longan (*lung yen*[6]), the litchi (*li chih*[7]), and trees of their kind flourish in the south. Trees like the hazel (*chên*[8]), the pine (*sung*[9]), the jujube (*tsao*[10]) and the chestnut (*li*[11]) grow well in the soils of the north ... This is inherent in the nature of things, humans cannot force them to achieve it. To reach their nature by truly following what Heaven has ordained for them, this is how you may plant and cultivate them successfully.

The literature on the distribution of species is scattered, but it builds up to an important body of knowledge about the environmental factors which operate on a site to maintain a particular association of species or ecosystem.

The earliest observations on the distribution of vegetation show an awareness of the differences between riparian and montane vegetation. Poems in the *Book of Odes* distinguish between trees that grow on the mountains and trees that

[a] Schafer (16), p. 119.

[b] The issue dominated statecraft and political philosophy, but we are of course talking here about achieving harmony between the elements in the context of agriculture and forestry.

[c] *Huai Nan Tzu*, ch. 1, *Yüan Tao Hsün*, 1, p. 1b. Transl. Morgan (1), p. 3.

[d] Cf. p. 619, above which translates a part of the parable.

[e] *CFP, I Li*[12], p. 1b.

[1] 道 [2] 天 [3] 郭橐駝 [4] 柳宗元 [5] 王象晉
[6] 龍眼 [7] 荔枝 [8] 榛 [9] 松 [10] 棗
[11] 栗 [12] 義例

grow in the swamps.[a] The *Ti Yüan Phien*[1] (Officers of the Land) chapter of the *Kuan Tzu*[2], which probably dates from the late Warring States period (−3rd century), is a study of the different soils and land forms of the Empire with an account of their vegetation. The importance of this chapter in a work on political economy is that the author is not content simply to state what is produced and where, but identifies why certain plants and trees are found in specific habitats. Factors identified as influencing the composition of species are the soil fertility and soil moisture content, altitude (related to the depth of the water table and expressed as the depth to which a well must be drilled before reaching water), slope and aspect.

The observations of the author of the *Ti Yüan Phien* are hardly to be improved on today. His remarks about the changes in vegetation with altitude perhaps place too much emphasis on the availability of water, and this was remedied over a millenium later during the Sung dynasty by Shên Kua[3]. In a brief passage describing his expeditions into the mountains to collect medicinal herbs, he suggests that the same plant will flower later during the season in the mountains than on the plains because of differences in temperature and in the phenology of the plant itself:[b]

> [Plants which are in] flower in the third month on the plains will only flower during the fourth month in the depths of the mountains. Pai Lo-Thien[4] [Pai Chü-I] says in 'A Poem on Visiting the Ta Lin[5] Temple', 'Among mortals, blossom loses its beauty and scent by April, when the peach is just coming into flower in the temples in the mountains.' This is a general principle. It is because of differences between high and low altitudes. Another example is the shoots of the *kuei*[6] bamboo. Some grow in the third month, some between the third and fourth months, and there are even some, called the late *kuei*, which only grow in the fifth month ... One crop grown in the same field can have early and late [growth], and this is because their natures (*hsing*[7]) are different.

(ii) *Ecosystems*

The search for harmony among the five elements led, as we have seen, to an understanding of some of the principles of autecology, the adaptation of organisms to their environment. The concept was applied in the form of recommendations to respect the ecological requirements of the species being cultivated. There is evidence that some thinkers, at least, took the premise of a universe formed by the workings of the five elements and used it to develop a vision of a world in which all matter and all living creatures were linked to and dependent on each other, a vision very similar to the contemporary concept of an ecosystem.

[a] See, for example *Thang Fêng, Shan Yu Ou*[8] 'Thorn Elms on the Mountain' and *Chhin Fêng, Chhên Fêng*[9] 'Swift is the Falcon', Karlgren (14), nos. 115 and 132 respectively.

[b] *Mêng Chhi Pi Than*, ch. 26, no. 484.

[1] 地員篇 [2] 管子 [3] 沈括 [4] 白樂天 [5] 大林
[6] 箭竹 [7] 性 [8] 山有樞 [9] 晨風

One of the mechanisms which links organisms within an ecosystem is the food chain. Plants and other primary producers convert solar energy into organic matter and are consumed by herbivores which are themselves consumed by carnivores in a chain of feeding relationships known as trophic levels.[a] The idea of a food chain is common in folk stories and proverbs the world over, and we find it in one of the stories in the Taoist classic, the *Chuang Tzu*:[b]

Chuang Chou was wandering in the park at Tiao Ling when he noticed a strange magpie coming from the south. It had a wingspan of seven feet, and its eyes were an inch across. It swept past Chuang Chou's forehead and alighted in a chestnut grove. 'What kind of bird is this?' said Chuang Chou. 'It has powerful wings but it will not leave, and it has big eyes but does not see.' He tucked up his skirts, took his crossbow and went to try and get it. Just then he saw a cicada enjoying the shade, forgetting all else. A mantis sprang to seize it, forgetting all else as it captured [its prey]. The strange bird took advantage of this and caught it, forgetting its own true nature as it made its capture [and approaching close to man]. Chuang Chou sighed and said, 'Alas! Creatures are by nature bound to each other (*wu ku hsiang lei*[1]). Different species prey on each other (*êrh lei hsiang chao*[2])'.

In his comments on this passage, Giles notes that the episode has been immortalised in proverbs and folk wisdom. He reports having seen a woodcut 'with the addition of a tiger about to spring upon the man, and a well into which both will eventually tumble. A legend at the side reads, – "All is destiny!" '[c]

The close relationship between habitat and species is hinted at in some early classifications of land use. The *Ti Kuan*[3] section of the *Chou Li* identifies five classes of land, each of which produces a particular combination of vegetation, produce and people. In the forests, for example, 'creatures that move are creatures with fur, the plants are dark in colour, and the people are hairy and thickset'.[d] The theme is developed in the *Ti Yüan Phien*[4] section of the *Kuan Tzu* already referred to above, which describes the distribution of vegetation in terms of the combination of environmental factors to be found in the mountains, the plains and the foothills, and is expressed succinctly in the *Huai Nan Tzu* in these terms,[e] 'If you wish to know the *Tao* of the earth, the trees are its material form.'

Many of these ideas about the environment are found in the *Fêng Shui*[5] system of geomancy. Rules about the location and orientation of dwellings and settlements had the effect of maintaining small areas of forest in sensitive watershed areas. It would not be an exaggeration to say that the remaining patches of forest in the densely populated landscape of southern China exist mainly because

[a] The concept of trophic levels was applied to ecosystems by Lindemann, and is the origin of the analysis of ecosystems in terms of energy budgets. See Lindemann (1) and Odum & Odum (1).

[b] *Chuang Tzu*, 20, *Shan Mu*[6], p. 54. Transl. Giles (15), adj. auct.

[c] Giles (15), p. 258.

[d] *Chou Li*, *Ti Kuan*, ch. 10, p. 3b. Transl. Biot (1), p. 194, adj. auct.

[e] *Huai Nan Tzu*, ch. 7, *Ti Hsing Hsün*[7], pp. 1–18.

[1] 物固相累 [2] 二類相召 [3] 地管 [4] 地員篇 [5] 風水
[6] 山木 [7] 地形訓

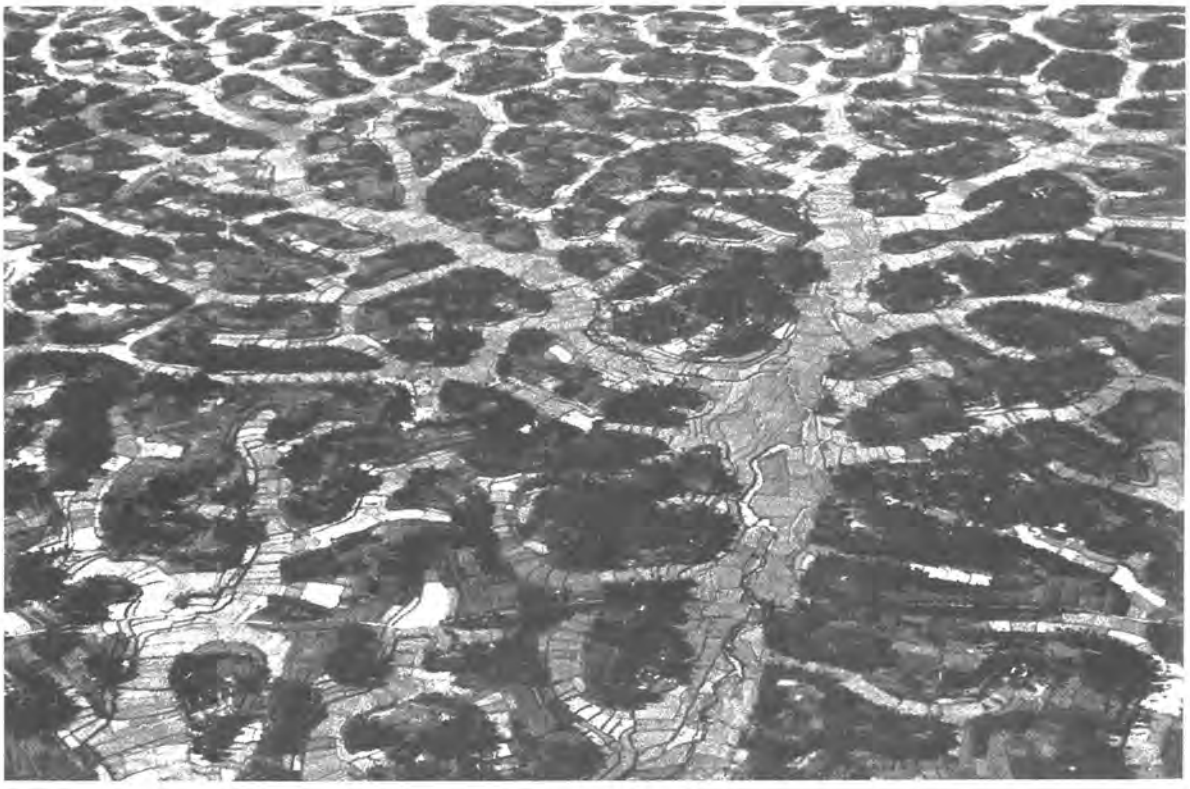


Fig. 134. Southern landscape with rice paddies in the valley bottoms and managed forest on the hilltops; from Koestler (1), opposite p. 580.

of the protection afforded them in the past by the concern for environmental stability embodied in geomancy (Fig. 134).[a] While *Fêng Shui* can be viewed as a system which applies ecological principles to land management and land utilisation, the analogy should not be pushed too far. Geomancy did result, to some extent, in the protection of the environment, but its theoretical framework was not sufficiently defined to allow it to advance from protection of the environment to the safe and rational manipulation of ecosystems managed to provide a continuous flow of useful products.

(2) Forest Influences: Soils and Water

Valleys between mountains are subject to much rain, and because of the dense forests, snow stands there much longer under the shadow of the trees and the hills. Then it melts and percolates through interstices of the earth and so reaches to the lowest spurs

[a] Fig. 134 shows a remarkable landscape in which vegetation is preserved on all the hilltops, possibly due to patterns of land use determined by geomancy. See Feuchtwang (1) for an analysis of geomancy as a system of environmental regulation.

of the mountains, from which the product of the spring flows and bursts forth. [Vitruvius, −1st century][a]

It has long been realised that there is a connection between deforestation, soil erosion and water supply. In ancient Greece, Plato compared the deforested hills of Attica to bleached skeletons,[b] and he also observed that where there has been deforestation, water no longer percolates into the soil to feed springs.[c] In China, where the first centralised States of the Shang and the Chou had their origins in the fertile but easily eroded loess soils of the north-west, the risk of erosion and of flooding was serious. It is significant that Yü the Great should have earned his place in the pantheon of mythical founding kings of China due to his work in controlling floods. The problem, it seems, has been present since the dawn of Chinese civilisation.

We have seen that Mencius deplored the deforestation of Ox Mountain (*Niu Shan*[1]), but his concern was that by uncontrolled timber cutting and overgrazing, humans had altered the nature of the mountain. He does not refer to the consequences of deforestation. An incident in the *Tso Chuan*[2], though, indicates an early awareness of a relationship between the cutting of trees and water. In the year −525, there was a severe drought in Chêng[3]. Envoys were sent to Mount Sang[4] to perform a rain sacrifice, and while there they cut down many trees. The rationalist statesman Tzu Chhan[5] said they had comitted a serious crime and had them punished accordingly.[d] The question of the relationship between forests, deforestation and climatic changes is still debated today, but Tzu Chhan appears to have believed that cutting the trees was one reason why the drought continued.[e]

The effects of deforestation on stream flows, on erosion, and as the cause of increased flooding, were of official concern from a very early date, since the Chinese State was so dependant on waterways for communications, and on adequate water supplies in agriculture. In the year −44, the Han statesman Kung Yü[6] made a speech attacking the economic policies of the time which had led to a rash of copper-mining to mint new coinage. Kung Yü observed that the disruptive effects of such uncontrolled mining extended beyond the immediate vicinity of the mines:[f]

They drill several hundred feet into the earth, destroying the essence of the Yin pneuma. The earth is plundered until it is empty, and is no longer able to hold the pneuma from which clouds are formed. They cut down the trees and forests, and they

[a] Vitruvius, *De Architectura* 8.1.6–7. [b] Plato, *Phaedo* 110E.
[c] Plato, *Critias* 117A.
[d] *Tso Chuan*, 16th year of Duke Chao[7], transl. Couvreur (1), vol. 3, p. 272.
[e] See pp. 555–8, above for a discussion on the question of deforestation and possible changes in the climate of north China.
[f] *Han Shu*, ch. 72, *Kung Yü Chuan*[8], p. 3075.

[1] 牛山 [2] 左傳 [3] 鄭 [4] 桑(山) [5] 子產
[6] 貢禹 [7] 昭(公) [8] 貢禹傳

ignore the prohibitions and the right seasons for cutting. Can we be sure that disastrous droughts will not be the result of this?

Prohibitions on cutting timber in the mountains were imposed by all the dynasties – although every dynasty was also responsible for violating the prohibitions to satisfy the demand for wood for Imperial building projects. The objective of these measures was usually to protect the forests as a source of timber, but there are some proclamations which specifically mention their beneficial effects on stream flow.[a] The Thang Emperor Hsüan Tsung[1] (r. +713 to +756) was particularly concerned with the question of conservation of natural resources, and he took action to protect the flow of water from the mountains near the capital city:[b]

> Mount Li [Black Horse Mountain],
> Peaks and tors bountifully upstanding,
> Looks down from near our suburb and demesne.
> Above, it divides the position Kên,
> So always perfuses clouds to create rains;
> Below, it emerges from hooded springs,
> Which wash out perverse beings, clean out wasting sickness.
> Indeed it is a place where numina and sylphs reside,
> A place looked up to by our domain and country.
> It is worthy of enlistment in the 'Concourse of Prospects',
> Of chronicling with the 'Integral Orders'.
> From now and hereafter
> Let the gathering of fuel be taboo there!
> Consider that a sealed precinct!
> Declare our will in this!

Of more serious concern to administrators was the siltation of canals and waterways caused by erosion following deforestation. The mechanisms of erosion are first discussed during the Sung dynasty. Shên Kua[2,c] wrote about the erosive effects of water and its importance in shaping the landscape in the *Mêng Chhi Pi Than* (+1086). Nearly two centuries later, Wei Hsien[3] (fl. 1242) saw deforestation as one of the main causes of siltation in the irrigation system of the Yangtse estuary. In his study of the problem, the *Ssu Ming Tho Shan Shui Li Pei Lan*[4], we find the first description of how forest vegetation protects the soil, regulating water flows and preventing flooding:[d]

[a] For an example from +457, see *Sung Shu*[5], ch. 54, *Yang Hsüan-Pao Chuan*[6], p. 1535.

[b] Hsüan Tsung, '*Chin Li Shan Chhiao Tshai Chhih*', *Chhüan Thang Wên* ch. 34, pp. 7a–7b. Transl. Schafer (22), p. 295. '*Kên*[8]' in line 4 is the hexagram meaning 'resistant; mountain; the northeast corner' which Schafer believes refers to its geomantic significance, indicating that the mountain was to the northeast of the city.

[c] *Mêng Chhi Pi Than*[9], ch. 24, *Tsa Chih*[10] 1, no. 433, *Yen Tang Shan*[11].

[d] *Ssu Ming Tho Shan Shui Li Pei Lan*, ch. 1, p. 6b.

[1] 玄宗 [2] 沈括 [3] 魏峴 [4] 四明它山水利備覽
[5] 宋書 [6] 羊玄保傳 [7] 禁驟山樵採勒 [8] 艮 [9] 夢溪筆談
[10] 雜志 [11] 雁蕩山

The scenic beauty of the waters and land of the Ssu Ming area lies in its many lovely mountains. In the past huge trees and tall forests lined the streams. In the plains, there were also thick, luxuriant bamboos and trees. Even if there was a thunderstorm, the sand and soil were held in the interlocking roots of the trees as they were washed away. Not much was washed down, so that there was little siltation, and it was easily loosened and scoured away. In recent years, because the price of timber has risen, axes seek out [the trees], and there is not a mountain which has not been left bare. The plains have also been cleared of the bamboos and trees. There are now no forests, so when there is heavy rain there is less resistance to water running off the slopes, and there are no obstructions to hold the particles of sand and soil (*sha thu chih miao*[1]). In this way, the soil is suspended and is carried down with the flow [of water]. It silts up and blocks the streams and waterways [with banks] up to forty or seventy feet in height.

Wei Hsien was well aware of the serious consequences of deforestation, but he does not seem to have considered it within his jurisdiction to promote reforestation in the mountains. His solutions to the siltation of the waterways were those of a hydraulic engineer, emphasising dyke building and maintenance. Vegetative methods were used, but as a means of strengthening the flood walls, not as a means of rehabilitating the denuded, eroding mountain slopes.[a]

The flooding and erosion caused by deforestation could have a devastating effect on agriculture. During the +16th and +17th centuries, the highlands of southern China were being settled by the shed people (*phêng min*[2]), who had little experience or understanding of slash-and-burn agriculture. Where they settled, they cleared the vegetation causing severe erosion and running of water off the slopes, which affected existing settled agriculture downstream. One of the many memorials and complaints about the settlers is of particular interest. During the early 19th century the Governor of Anhui province opened up the highlands of the province to settlement by the shed people. His action was criticised by the scholar Mei Tshêng-Liang[3] (style Po-Yen[4]; +1786 to +1856) who wrote a memorial 'On the Subject of the Shed People' (*Shu Phêng Min Shih*[5]). To allow the shed people to clear the mountains, wrote Mei, would be 'to open up sterile land while harming fields that grow grain'. The memorial gives the by now familiar litany of streams choked with debris and of floodwaters overwhelming the carefully tended rice fields in the valleys but it adds considerably to earlier accounts of the protective influence of forest vegetation with an explanation of how foliage intercepts rainfall, and how water percolates through the humus layer on the forest floor:[b]

If you ask people in the country, they will all tell you that on a mountain that has not been cleared the soil is stable and the rocks stay firmly in place. Grass and trees grow thickly, and rotting foliage can accumulate to a depth of two or three inches in a few

[a] Cf. Vol. 4, pt 3, sec. 28 on hydraulic engineering and the different solutions proposed to the problem of siltation.

[b] *Shu Phêng Min Shih*, p. 17a.

[1] 沙土之苗 [2] 棚民 [3] 梅曾亮 [4] 柏言 [5] 書棚民事

years. Whenever it rains, the rain makes its way down the tree along the leaves. From the leaves it makes its way to the rocks. It passes through fissures in the rocks and droplets trickle together to form springs. The water [flows] gently downward and as the water goes down, it does not carry the soil with it. Since the water flows gently, there are no disasters when it is received in the fields below.

The official strategy most commonly adopted to protect the forests was to prohibit access to the mountains (*Fêng shan*[1]), a notoriously difficult policy to enforce in remote and rugged country. Attempts were also made to regulate land clearance with systems of land classification according to which steep slopes were declared unsuitable for grain and agricultural crops. Land classification has a long history in China, and we have already seen the principles of the system used in the *Kuan Tzu* of the −3rd century. In a densely populated country, the pressure to open up uncultivated land can be difficult to resist even when the consequences are well known. Local histories of south China contain many descriptions of the hazards of converting forest to agricultural land[a] but the solution to the problems of erosion and flooding was not easily found. Edicts addressing the problem of land clearances by the shed people failed to make much impression, perhaps because the only alternative the authorities could propose to grain crops was the cultivation of fruit trees or sericulture, sanctioned by centuries of Confucian tradition, but not immediately applicable to the requirements of pioneer agriculture in the mountains.[b]

(*f*) FORESTRY IN CHINESE SOCIETY

(1) Causes of Deforestation

Given the knowledge of silviculture and forest management displayed in the literature, we must ask why the forests of China were subjected to such apparent plunder and destruction. The immediate response is that a continuous increase in agricultural production was needed as the population grew, with the result that forest was converted to agricultural land. Population pressure is undoubtedly a factor influencing the course of forest clearance, but it is far from evident that demographic pressures inevitably lead to deforestation, or that their absence allows forests to remain intact.[c]

In Tokugawa Japan (+1600 to 1867), earlier deforestation had caused timber

[a] Several are quoted in Chhên Chhiao-I (*3*). See also the +1733 *Shan-Hsi Thung Chih*[2], ch. 66, p. 31a, translated in vol. 4, pt 3, p. 245, and the +1762 *Fu Ning Fu Chih*[3], ch. 12, p. 24b.

[b] See for example the text of an edict issued in the second year of the Yung Chêng period (+1725) in the +1878 *Shan-Hua*[4] *Hsien Chih*, ch. 16, p. 1b.

[c] This raises the question of the relationship between population, agricultural technology, and the intensity of land utilisation. The question is at least as old as Malthus. More recently, Boserup has stressed the importance of population growth in stimulating the intensification of agriculture. See Boserup (1). See also Vol. 6, pt 2, pp. 596–7.

[1] 封山 [2] 山西通志 [3] 福寧府志 [4] 善化(縣)

shortages, while the threat of flooding and erosion had a serious impact on agriculture.[a] Under these circumstances, decisions about land utilisation balanced forest conservation against conversion to agriculture, and intensive reforestation efforts were carried out. Japan, one of the world's most densely populated countries, was able to implement a decision to conserve forests and still boasts a higher percentage of forest cover than many comparable countries with a lower population density.

The factors which led to deforestation can be classified into three broad categories, acting alone or in combination at any particular time or place. Forests might be cleared to make land available for other purposes, usually agricultural. They might be cut for timber, fuelwood, and other forest products. Finally, forests played an ambivalent role in national security. At times they were protected as a barrier against invasion, and on other occasions they were cleared to remove potential hideouts for enemies or bandits.

The process of land conversion continued throughout Chinese history, punctuated by disruptions such as warfare and rebellion. The population of south China experienced uninterrupted growth between the +7th and the +11th centuries, while the population of the north fluctuated, and even declined in some areas.[b] Pulses of migration due to warfare and rebellion in the north characterise the history of the settlement of south China, and set the pattern in the south of deforestation due to land clearance. There was a large influx of refugees from the north at the time of the flight of the Sung court to Hangchow[1] in +1127. The loss during this period of the remaining forests in the Hui Chi[2] and Ssu Ming[3] mountains on the edge of the Yangtse estuary,[c] is just one example of deforestation following increased pressure to open up land due to a sudden increase in the population.

Technological, economic and social factors all gave impetus to land conversion of previously marginal land. The popularisation of tea as a commercial crop in south China made hill farming profitable where conditions were appropriate for its growth.[d] The rapid adoption of maize and sweet potatoes during the +16th and +17th centuries has already been referred to above as instrumental in opening some of the steepest and most remote sites to settlers, with serious consequences for lowland agriculture from soil erosion and stream siltation.[e]

Political concerns could govern the pattern of clearance in sparsely populated regions. Concern during the +16th and +17th centuries about land clearance by the shed people was aggravated, or maybe even prompted by their indepen-

[a] Totman (1), pp. 417–18.
[b] Elvin (2), pp. 204–15.
[c] Cf. p. 563, above.
[d] See p. 563, above.
[e] See pp. 563–4, above. On the introduction of New World Crops, see vol. 6, pt 2, p. 458.

[1] 杭州 [2] 會稽(山) [3] 四明(山)

dent way of life, beyond effective official control.[a] Unoccupied or barren land represented a vacuum over which the central authorities attempted to extend their control by encouraging directed settlement. Forced migrations, and military settlements, the *thun thien*[1], were frequently used to this end. These settlements were usually along the northwestern frontier with Central Asia, but it was not unusual for settlements to be established inland. It was also common to reward government troops with land grants following the suppression of a rebellion, particularly in areas inhabited by ethnic minorities.[b] Whatever form the government action took, the result of these policies was to convert large areas of forest and grassland to agricultural use. One estimate suggests that during the Hung-Wu[2] period of the Ming dynasty (+1368 to +1399), up to 25 per cent of the total arable land was operated by *thun thien* military colonies.[c]

With due regard to the importance of land conversion as the most permanent form of deforestation, it is time to consider the use of forests for fuel and timber. Wood has been used as the main source of fuel, both domestically and industrially from earliest times (Fig. 135).[d] The effects on the forests of cutting for fuelwood and charcoal are hard to gauge, because this is the least documented form of wood utilisation.[e] It is interesting to note though that in some early texts, fuel for domestic purposes is said to come from grasses or brush. The *Kuan Tzu*[3] describes the areas of scrub vegetation (*tsê*[4]) in the northern part of the State of Chhi[5] as an important source of cooking fuel. The words used are *hsin*[6] and *jao*[7], both of which are written with the graph for grass, not wood.[f]

Demand for fuelwood experienced in the cities has already been mentioned as influencing the planning of transport systems and canals.[g] The availability of fuel was also a factor in the location of industries such as iron and ceramics. By the +11th century, the largest metallurgical enterprises were able to take advantage of technological innovations allowing the substitution of coal for charcoal in smelting, and became concentrated close to deposits of the new fuel.[h] In some cases, systems of coppicing and pollarding were developed with the sole objective of ensuring a regular supply of fuelwood.[i]

[a] See (*c*) (4) (ii), above.

[b] Chiang Thai-Hsin[8] (*1*). Shaw (1), p. 95, described this process taking place in Kuei-Chou, following a rebellion by the Miao.

[c] Yang Shêng-Min[9] (*1*), p. 109.

[d] Forests were a source of other forest products, of course. One of the most common uses of pines was for the extraction of resin, and for soot used in making ink. In the +11th century, Shên Kua complained that the hills around Lo-Yang had been denuded to provide pine soot needed for the ink used by scholars in the capital (*Mêng Chhi Pi Than*, ch. 24, vol. 2, p. 745).

[e] While the extraction of such 'minor forest products' could be a significant source of forest clearance, the use of forests for fuel and timber has almost certainly had a greater impact on the landscape.

[f] *Kuan Tzu*, *phien* 80, ch. 23, p. 14b. The word *hsin* is still commonly used today in the binomial *hsin chhai*[10] meaning fuelwood. On the meaning of *tsê*, 'scrub vegetation', see Bodde (32).

[g] See pp. 640–2, above.

[h] Hartwell (1), pp. 108–10.

[i] Cf. Wagner (1), p. 33, and Chhên Jung (*2*), pp. 52–3.

[1] 屯田 [2] 洪武 [3] 管子 [4] 澤 [5] 齊
[6] 薪 [7] 蕘 [8] 江太新 [9] 楊生民 [10] 薪柴

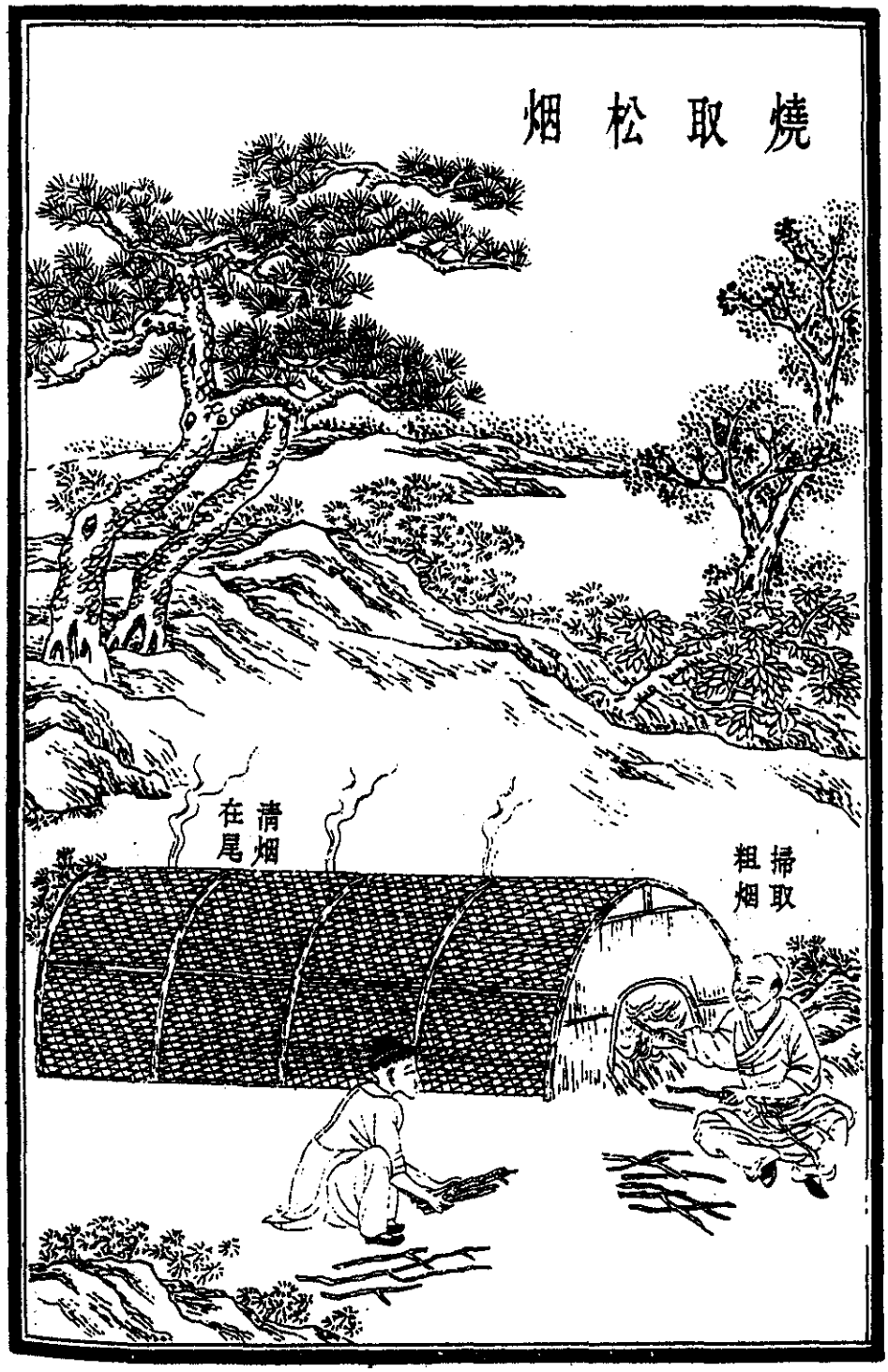


Fig. 135. Preparation of pine soot to make ink; from *Thien Kung Khai Wu*, Chung Hua Tshung Shu edition, Taipei, 1955, p. 412.

The use of wood for construction has probably been somewhat exaggerated by an emphasis in research on the ceremonial architecture of palaces and temples. Houses built entirely of wood were already unusual enough by the −1st century to be considered worthy of special comment. Describing the area of the upper Wei[1] river in modern Kan-Su, the Geographical Treatise of the *Han Shu* says 'The people use planks to build their homes'.[a] The structure of dwellings excavated at early urban sites such as An-Yang[2] is similar to the style of domestic architecture seen in villages all over China today. A framework of wooden posts was constructed, which was then filled in with the most readily available materials such as tamped earth or wattle and daub.[b] This restrained use of wood suggests that timber may always have been a rather scarce resource.

If domestic architecture was characterised by the sparing use of wood, all restraint was set aside when building official structures such as temples and palaces. The strain on forests was particularly severe when a newly established dynasty sought to consolidate its authority by building a new capital, for which huge quantities of timber were needed.[c] The episodic nature of these periods of intensive construction meant that permanent damage to the forests was unlikely since there was ample time for regeneration and recovery to take place during the intervening centuries. More serious deforestation took place in areas which had had the dubious privilege of being chosen to provide for the requirements in wood of the Imperial household. In 1487, Chhiu Chün[3], who was later to be appointed President of the Board of Rites (*Li Pu Shang Shu*[4]), wrote that the forests of I-Chou[5] (Ho-Pei province) were being destroyed because of the unrelieved pressure of wood requisitions. He proposed a system of timber procurement which would, if adopted, have spread the burden more equally over the whole country, and might have prevented the deforestation of many northern counties and prefectures.[d]

The strategic value of forests in the northern borderlands lay in the simple fact of their presence, a hindrance to advancing armies of horsemen from the treeless steppes of Central Asia. This passage from the gazetteer of the sacred mountain of Wu Thai Shan[6] in Shan-Hsi explains their importance:[e]

The boundary between China and the barbarians is one separating mountain range. Fortunately between Pei-lou and Ning-wu forests are flourishing and thick, serving as a protecting fortification, and the mountain of Wu Thai, with its numerous ridges and dense forests, was relied on as an inner barrier.

[a] *Han Shu, Ti Li Chih*[7], ch. 28, p. 1644.
[b] Chang (5), pp. 90–9.
[c] Yang (11), pp. 35–40.
[d] *Ta Hsüeh Yen I Pu*[8], ch. 150, p. 3b.
[e] *Chhing Liang Shan Chih*[9], Wan Li[10] ed., ch. 5, p. 25b. Transl. in Lowdermilk & Wickes (3), p. 1.

[1] 渭 [2] 安陽 [3] 丘濬 [4] 禮部尚書 [5] 易州
[6] 五臺山 [7] 地理志 [8] 大學衍義補 [9] 清涼山志 [10] 萬歷

When actions were taken to protect forests in these border regions, national security was often one of the stated objectives.[a] In fact the earliest example of officially sponsored tree-planting on a large scale is the defensive palisade of elm trees planted along the Great Wall of Chhin Shih Huang[1] (c. −221).[b]

Internally, the converse was often true. Forests in the interior of China were notorious bandit hideouts. Some of the most exciting ambushes and rescues in the medieval novel, 'The Water Margin' (*Shui Hu Chuan*[2]) take place in the depths of the forest. One +16th-century travelogue gives a colourful account of a band of warrior monks who used their fighting skills to protect mines they operated in a remote forest. The monks 'tunnelled into the mountains by profession and made a living by killed people ... they were believed in the city to devour people like tigers and then to spit them out'.[c] The danger of travel through forests was a serious impediment to communications and trade. As a result, orders were frequently given to clear all trees from threatened routes. In +1598, forest was cleared for six hundred *li* along both banks of the Fu[3] River in Ssu-Chhuan where bandits had been using grappling irons to capture and plunder boats carrying commercial traffic.[d] In +1644, immediately after the Manchu takeover of Peking, landowners south of the city were given three days to cut all the trees along the roads, to clear the region of bandits.[e] The significance of this form of forest clearance is greater than might be assumed from the area of forest detroyed. The removal of forest along major communications routes would give settlers easy access to unoccupied land, encouraging large-scale and permanent conversion to farmland.

(2) The State and Forestry

The environmental degradation which was a consequence of deforestation did not pass unnoticed or without comment. Mencius saw the deforestation of Ox Mountain (Niu Shan[4]) as violating the true nature of the mountain. We have already mentioned the local gazetteers in which administrators wrote about flooding and siltation, which they knew very well to be the result of forest clearance in the mountainous hinterland. From the legendary forester Po I[5], to the contemporary Ministry of Forestry, governments of China have all recognised a need to exert some form of administrative control over the utilisation of the forests. Given the complexities of the factors contributing to deforestation, it is

[a] See, e.g. the prohibition of timber felling in the Wu Thai Shan area in +1580, *ibid.*, ch. 5, p. 25b.
[b] See p. 586, above.
[c] *Kuang Chih I*[6], ch. 3, p. 10a.
[d] *Ibid.*, ch. 5, p. 15b.
[e] The text of the order is in Hsieh Kuo-Chên[7] (*4*), p. 54. I am grateful to Professor Frederick Wakeman for bringing it to my attention.

[1] 秦始皇 [2] 水滸傳 [3] 府 [4] 牛山 [5] 伯益
[6] 廣志繹 [7] 謝國楨

not surprising to find that awareness was not always translated into decisive action to protect forests or to develop sustainable systems of management.[a]

The ancient terms *Yü*[1] and *Hêng*[2], originally applied to forestry officials in the *Chou Li*[b] were later used to designate offices and boards with jurisdiction over the forests. During the early Imperial period, separate agencies existed to watch over timber supplies and public works, and the Imperial Preserves.[c] A similar division of responsibilities between institutions concerned with agriculture and public works was found in the Sui and Thang. During the Sui dynasty, the *Ling Yü Tshao*[3] (Board of Forests), under the *Kung Pu Tshao*[4] (Board of Works), was charged with regulating forest utilisation. The Office of Agriculture (*Ssu Nung Ssu*[5]) collected the revenues from agriculture and forestry, with smaller departments responsible for managing the Imperial Preserves, and for supervising timber supplies.[d]

State control over sales of timber was established in the year +973, allegedly to prevent profiteering by officials who had been taking advantage of their position to procure and sell timber.[e] From this point on, the State extended its interest in forestry to the regulation and control of the supply and distribution of timber and wood products. During the +13th century, the Yüan established a 'Bureau for the Exploitation of Mountains' (*Shang Tu Tshai Shan Thi Ling So*[6]), and a 'Timber Yard' (*Mu Chhang*[7]) to administer the procurement of timber for the Imperial household and for officially sponsored building projects.[f] These institutions were later called 'Imperial Timber Factories' (*Huang Mu Chhang*[8]). The hardship and suffering caused by their voracious appetite for timber have already been described as a cause of disaffection and insurrection in the forested regions where the timber was cut.[g]

When measures for the conservation of forests were adopted, they attempted to limit access to the resource. The duties of the *Shan Yü*[9] (Superintendent of the Mountains) and the *Lin Hêng*[10] (Inspector of the Forests) as described in the *Chou Li*, were divided between the administration and enforcement of regulations controlling utilisation of the forest:[h]

[a] For historical surveys of the forestry administration of China see Wang Hsi-Liang (*1*) (on the Sung dynasty only), and Wang Hsi-Liang (*2*) (a survey of all the dynasties).

[b] *Chou Li, Ti Kuan*[11], ch. 16, pp. 10b–12b.

[c] Wang Hsi-Liang (*2*), p. 55. The Imperial Preserves were not managed for timber. They were maintained at times as Imperial parks, at other times as hunting preserves – a particularly important use during the Chhing dynasty. Cf. Ho-Pei Shêng Wên Wu Kuan Li Chhu, Chhêng-Tê Ti Chhü Wên Hua Chü, Wei-Chhang Hsien Wên Kuan Hui (*1*).

[d] *Ibid.*, p. 57.

[e] *Ibid.*, p. 58.

[f] *Ibid.*, p. 58.

[g] See pp. 637–8, above.

[h] *Chou Li, Ti Kuan*, ch. 16, pp. 10b–12b. Transl. Biot (1) adj. auct. pp. 370–4.

[1] 虞 [2] 衡 [3] 領虞曹 [4] 工部曹 [5] 司農司
[6] 上都采山提領所 [7] 木廠 [8] 皇木廠 [9] 山虞
[10] 林衡 [11] 地官

The Superintendents of the Mountains are in control of the administration of the mountain forests. They determine which species are to be protected, and establish the prohibitions for their conservation ...

The Inspectors of the Forests are in control of the prohibitions which apply to the forests of the foothills and ensure that the task of guarding them is distributed fairly.

Frequent prohibitions of timber-felling were imposed, both over the whole country and in areas where deforestation had been particularly severe. During the +15th century, after the Ming capital had been moved to Peking, a ban in the area on cutting wood remained in force long enough for the forests to recover from the damage they had suffered from the building programmes of the preceding Yüan dynasty.[a] In general, though, prohibitions on felling proved to be an unsatisfactory way to protect forests. Their effectiveness depended on the ability and willingness of the local authorities to enforce them. Corruption on the part of officials, or the desperate need of the inhabitants to obtain firewood could make the orders meaningless. The problem of enforcement was raised in a report to the throne on the subject of the prohibition imposed on the area surrounding Wu Thai Shan which has already been mentioned above.[b] In this case, monks from the temples on the sacred peak were appointed to guard the forest but, in due course, even they were guilty of illegally cutting and selling timber.

Prohibitions on felling were rescinded when there was a conflict with other State interests. Wang Chiu-Ling has counted more than ten orders relaxing prohibitions on cutting during the brief period of eighty-nine years in which the Yüan dynasty controlled the whole of China.[c] At times of particular need, even protected monastic forests were felled on government orders. During the +16th century, when pirates plundered the southern coastal provinces, the trees surrounding the Ling Yin Ssu[1] monastery near Hangchow[2] were cut to build boats to patrol the coast, and even the large bronze bell was melted down to make cannons.[d] The physical difficulties of enforcing prohibitions, compounded by policies governed by changing national priorities, weakened the potential effectiveness of official protection of the forests.

When there was official interest in promoting forestry, it took the form of encouraging the planting of trees, and especially of mulberries for sericulture, within the agricultural system. The land distribution systems of the medieval dynasties (from the Wei until the Thang) included the provision of a block of land (*yung yeh thien*[3]) to be held in perpetuity by the household on the condition

[a] Wang Chiu-Ling[4] (1), p. 39.
[b] *Chhing Liang Shan Chih*[5], Wan Li ed., ch. 5, p. 25b.
[c] Wang Chiu-Ling (*1*), p. 38.
[d] *Ling Yin Ssu Chih*[6], Khang Hsi ed., ch. 8, p. 11a. I am indebted to Timothy Brook for drawing my attention to the literature on monastic forests.

[1] 靈隱寺 [2] 杭州 [3] 永業田 [4] 王九嶺 [5] 清涼山志
[6] 靈隱寺志

that suitable trees were to be grown there.[a] This emphasis reinforced the association between Chinese forestry and agriculture. There are other reports of Imperially sponsored tree planting in the cities.[b] Finally, tree planting was an essential part of large-scale public works such as canal building where trees were planted to reinforce the dykes, and the strategic barriers of trees along the Great Wall and the northwestern frontier.

The case of canal-side plantings raises a final point on the subject of the limitations of official actions taken to respond to the problems caused by deforestation. Wei Hsien[1], the author of the +13th-century *Ssu Ming Tho Shan Shui Li Pei Lan*[2], knew very well that siltation of canals was the result of deforestation in the mountains.[c] His proposals for remedying the problem did not, however, consider the possibility of reforesting the water catchment. Wei Hsien, the engineer, limited his attention to the area over which he had direct control. His solution was to strengthen the dykes and to clear the water channels. Willows were used to strengthen the dykes and elaborate systems were devised for planting them.[d] Although it was known that the genesis of the problem was to be found upstream, labour and energy were invested in the resolution of the immediate problem of strengthening the dykes.

The proposals referred to above to adjust the system of timber procurement made in +1487 by Chhiu Chün constitute a remarkable precursor of what would now be called an 'integrated project' to confront the problem raised by deforestation. He saw that the problem was a complex one, which would only be resolved by a combination of measures designed not only to halt excessive cutting of timber, but also to remove the need for overcutting. Not content with alleviating the pressure on the forests of Ho-Pei by spreading the burden of timber requisitions more fairly around the country, Chhiu Chün also suggested a vast programme of reforestation:[e]

> Starting at Shan Hai Kuan[3] in the east and heading westwards almost as far as the boundaries of the interior territories, trees should be planted along the mountains, following the line of the frontier passes. They should be as broad or as narrow, as steep or as variable as the topography allows. One objective is to ensure a supply of fuelwood, another objective is to screen the frontier.

[a] During the Thang dynasty, elm, jujube, and mulberry were to be planted. *Thang Shu*[4], *Shih Huo Chih*[5]. In Wang Hsi-Liang (*2*), pp. 56 and 57.

[b] *Thien Fu Kuang Chi*[6], ch. 21. Also see Ong Chün-Hsiung[7] (*1*), p. 58.

[c] See pp. 652–3, above.

[d] Cf. 'Six Ways of Using Willows to Control the River' (*Chih Ho Liu Liu*[8]) by Liu Chuang-Hsiang[9], see pp. 617–18, above.

[e] Chhiu Chün, *Ta Hsüeh Yen I Pu*, ch. 150, p. 5a. The plan is very similar to current proposals to establish a 'Green Great Wall' of forests and shelter belts to protect the North China Plain from the sands of the Gobi Deserts.

[1] 魏峴 [2] 四明它山水利備覽 [3] 山海關 [4] 唐書
[5] 食貨志 [6] 天府廣記 [7] 翁俊雄 [8] 治河六柳 [9] 劉莊襄

If it had been adopted, this visionary plan which included incentives to the inhabitants in the form of tax relief as well as guidance in the selection of appropriate species to plant, could have been a model for rehabilitating deforested areas of northern China. As it was, the proposals were ignored, and the people of Ho-Pei are still fighting the consequences of deforestation today.

(3) Conclusions

We have distinguished between intensive forestry, practised as one element within agricultural systems, and extensive forestry, practised as a distinct form of land use, in which natural forests are managed for the production of timber and other forest products. With some exceptions, forestry in China fell into the former category, characterised by small areas planted with trees supplying the needs of nearby consumers.

The Chinese tradition of forestry is very different from the contemporary emphasis on extensive forestry, but is not without parallels in the ancient world.[a] The works of Roman agronomists such as Cato and Columella gave advice on growing trees such as chestnut, elm, willow and poplar. In a list of crops grown on an estate, Cato places the willow-bed third, coppice wood (*Silva caedua*) seventh, and mast-wood (*Glandaria silva*) ninth in order of profitability.[b] The mast-wood was natural forest surrounding, or forming a part of the estate in which pigs fed on the acorns and beech nuts. Forest grazing of pigs and livestock does not seem to have been practised in China,[c] although the +6th-century *Chhi Min Yao Shu* does mention the value of acorns for fattening pigs.[d] The importance of the willow bed and the coppice wood in Roman estates is, however, mirrored in the Chinese agricultural manuals, and in scattered references to arboriculture before the *Chhi Min Yao Shu*.[e]

Differences between Western and Chinese forestry are more apparent after the fall of Rome. In northern Europe, the requirements of the population for timber were satisfied by cutting natural forests, with coppicing and pollarding used to supply small wood on a regular basis. Intensive systems of tree cultivation were still practised close to centres of population in Arab Andalusia, where harsher climatic conditions made natural regeneration of forests difficult.[f] In China the tradition of intensive cultivation of trees continued, with the addition of new species, and the adoption of techniques such as cutting and planting out stump sprouts for regeneration.

[a] The most thorough studies of forestry in Classical Greece and Rome are to be found in Bérenger (1) Meiggs (1). This discussion relies heavily on their work.

[b] Cato, *De Agricultura* 1.7.

[c] Chang Kwang-Chih suggests that pigs, cattle and other domestic livestock was raised in pens and enclosures as early as the –2nd millenium. Chang Kwang-Chih (5), p. 143.

[d] *CMYS*, ch. 50, p. 293.

[e] See (*c*), above.

[f] Ibn al 'Awwām, esp. chapter 7.

The late +16th century and early +17th century were a time of rapid change in European forestry. The German States had a long tradition of careful utilisation of forests, but this was mainly the result of controlling access to forests, and of regulating their use.[a] In France, the first reference to a silvicultural prescription to bring an extensive tract of forest under a system of sustained yield management dates from +1579.[b] By +1611, Standish had written the first manual in English on reforestation, his objective being to explain 'how to plant wood according to the nature of every soyle, without losse of any ground: and how thereby many more and better cattel may be yeerely bred, with the charge and profit that yeerely may arise thereby'.[c] The development of forestry in Europe after the +16th century was uneven and suffered many reverses, but the basic pattern of extensive management of natural forests was to continue until the present.

The consistent official policy in China of 'emphasising agriculture' (*chung nung*[1]) must be counted as a factor which guided the development of forestry in China. To point to this policy as having focused undue attention on agriculture at the expense of extensive forms of land use such as grazing or forestry, raises the question of why agriculture was of such importance. At the risk of being accused of environmental determinism, it seems that the ecological conditions of north China were sufficiently unique to warrant a characteristic adaptive response on the part of the people who settled there and laid the foundations of the Chinese State. The climate of north China may have been more humid than it is now,[d] but the frequency of oracle-bone inscriptions requesting rain, or requesting that the rain should fall at the right time and in sufficient quantity, suggests that precipitation could be unreliable. The friable loess soils on which the Chinese agricultural systems evolved demand careful husbanding if fields are not to be lost to erosion from wind or rain. The intensive agriculture typical of China, with an early emphasis on techniques of soil preparation, fertilisation, and irrigation was a response to these natural conditions[e] and State interest in maintaining the vital economic base of agriculture was reflected in the emphasis on agriculture and sericulture.

Forests played a crucial role in the economy of Europe following the fall of

[a] Glacken (1), pp. 333–41, examines the role of forests in Central Europe from the time of Charlemagne to the dawn of the Renaissance.

[b] The system used was '*à tire et aire*' which consisted of an orderly succession of clearcuts. Under earlier systems, individual trees in a stand were selected for cutting which was said to lead to a deterioration in the quality of growing stock. Badré (1), p. 50.

[c] Standish (1).

[d] I am grateful to Dr. David Keightley of Berkeley, California, for time spent with me discussing his views on rainfall in Shang China.

[e] A similar point is made by Ho Ping-ti, but he perhaps overemphasises the harshness of the environmental conditions of the loess plateau, and sees early Chinese society as being moulded by these conditions rather than developing in response to them. The distinction here is between passivity and creative adaptation. Ho Ping-ti (6).

[1] 重農

the Roman Empire. They provided forage and pasture for livestock, timber for construction, and fuelwood for domestic and industrial needs. Beekeeping was an important occupation, and hunting was, for a long time, an important source of protein, not just a sport for the nobility. So essential were these products that throughout medieval Europe, a complex web of rights and obligations was woven over the forests, which regulated their use, and prevented uncontrolled clearance and conversion to farmland. When the English barons forced King John to sign the Magna Carta in +1215, four clauses of the charter asserted their rights over forested land.[a] There are even reports that in Germany the energetic clearance of forests by monasteries was occasionally halted as a result of confrontations between monks and forest guards appointed to safeguard the rights of traditional users.[b]

The use of timber in building notwithstanding, forest products played a lesser role in China. Hunting was an important occupation in the Shang royal household, but the quantity of bones of domesticated livestock excavated at An-Yang suggests that hunting was not a vital source of food.[c] The question of land tenure in China is complex and will be examined in detail in Volume 7, but rights to land were nearly always defined in terms of agricultural use. Security of tenure lay in agriculture, and wood could be grown on agricultural lands to supply the everyday requirements for construction and fuelwood, whereas the instability of tenure and usufruct rights in forested areas was a disincentive to managing them on a long-term basis for timber production.

A final question to consider is that of the effects of timber scarcity. The first problem to address here is the meaning of the term scarcity. Scarcity is not an objective state with fixed parameters by which it can be identified. The absolute absence or physical scarcity of a good must also be distinguished from economic scarcity. The latter is related to economic factors of supply and demand and is usually reflected in higher real market prices for the good.

A sequence of events could be visualised in which deforestation leads to a shortage of timber, which slows economic development due to shortages of fuel for industry. This in turn prompts technological changes to surmount the crisis.[d] We have already noted, however, that a high demand for timber did not inevitably lead to the destruction of forests. Economic historians have proposed a more complex relationship between supplies of wood, technological change, and economic development. They argue that decisions to substitute one form of energy for another were made on the basis of technological feasibility, and the cost of the fuel. In the case of coal and charcoal in England, the cost of labour and transport in charcoal production was more of an incentive to sub-

[a] James (1), chapter 1.

[b] Cf. Glacken (1), pp. 326–41, on utilisation of forests during the early medieval period. Also, Darby (1).

[c] Chang Kwang-Chih (5), pp. 142–3.

[d] This hypothesis has been proposed many times in the study of the Industrial Revolution. See Nef (1), Albion (1), and Clow and Clow (1).

stitution than a shortage of timber. When the technology was available to use coal for smelting iron, it was rapidly adopted. M. Flinn adds that the production of iron in England in the +17th century shows no evidence of having been restricted by shortages of charcoal.[a] He believes, in fact, that the growth of the industry encouraged landowners to manage woodlands for charcoal production, which was more financially rewarding than conversion to agriculture.

This argument has the merit that it recognises that permanent deforestation is more often the result of forest clearance and conversion to agriculture than of timber harvesting alone. It also suggests some possible answers to the question of why forestry practices in China and Europe diverged, although much research is needed on the question of the relative values of agricultural land and wildland, and on the prices and supply of charcoal and coal. In Europe, during the period of economic growth of the +16th century, fuel and timber for construction were supplied most economically by an expansion of forest management. Coppicing produced a reliable crop of wood for charcoal,[b] while improved methods of silviculture and forest mangement were devised to resolve the question of supplying construction timber and naval supplies.[c] When the technology was developed to use coal in smelting iron, extensive forestry remained as the common form of forest management for timber and other wood products.[d]

In China, the technology for using coal in iron smelting was available much earlier than in Europe.[e] The early availability of coal as a substitute for charcoal meant that there was little incentive to practise extensive forestry to fuel the growth of industry. By the late +12th century, however, the economic equation involving the demand for iron, and the relative costs of charcoal and coal favoured the widespread adoption of coal. Improvements in agricultural technology at the time may also have altered the equation by changing the relative values of land used for agriculture and for forestry.[f] The major demands for wood, then, were for domestic fuelwood and for construction. The existing intensive systems of forestry were able, with some improvements, to meet these needs for wood, although it would seem that by the late Imperial period, the potential of this form of forestry was reaching its limits, leading to the severe shortages of wood described by Western travellers in the 19th century.

[a] Flinn (1), p. 117.

[b] The growth of the iron industry in northwestern France led to the conversion of large areas of forest to coppice. Many landowners welcomed iron foundries as offering the only way to derive an income from otherwise useless land. Dornic (1).

[c] James (1), chapter 7, and Badré (1), pp. 71–101.

[d] Coppicing was still practised to produce charcoal and fuelwood for domestic heating until well into the twentieth century.

[e] Some Chinese archaeologists believe that coal was used as early as the late Western Han period (at the turn of the −1st and +1st millennia). [Pei-Ching Kang Thieh Hsüeh Yüan ... (1)]. Cf. also, Vol. 5, pt 6, on ferrous metallurgy.

[f] The situation would seem to have been different in south China where plantations of cunninghamia proved to be a more valuable and sustainable form of land use than agriculture.

As we leave the subject of forestry in China, it is worth turning from the question of why extensive forestry did not develop in China, to a reminder of what intensive forestry could achieve. In 1930 Lowdermilk observed in his survey of forestry in China that even on the apparently treeless North China Plain, enough timber was produced not only to satisfy the admittedly modest requirements of the inhabitants, but that logs were even exported to Japan:[a]

> It may be a surprise to learn that the great delta plain of the Yellow River not only grows the timber that it uses, but actually exports considerable quantities of logs of *Paulownia tomentosa* to Japan for sandals and poplar (*Populus tomentosa*) to match factories. It is true that no forests are to be found on this plain, but each village has its trees, which are grown according to a system. Nurseries dating back to ancient times are still in existence to supply seedlings and cuttings for planting.

[a] Lowdermilk & Li (1), p. 11.

BIBLIOGRAPHIES

A CHINESE AND JAPANESE BOOKS BEFORE +1800, AND ALL GAZETTEERS

B CHINESE AND JAPANESE BOOKS AND JOURNAL ARTICLES SINCE +1800, EXCLUDING GAZETTEERS

C BOOKS AND JOURNAL ARTICLES IN WESTERN LANGUAGES

In Bibliographies A and B there are two modifications of the Roman alphabetical sequence: transliterated *Chh-* comes after all other entries under *Ch-*, and transliterated *Hs-* comes after all other entries under *H-*. Thus *Chhên* comes after *Chung* and *Hsi* comes after *Huai*. This system applies only to the first words of the titles. Moreover, where *Chh-* and *Hs-* occur in words used in Bibliography C, i.e. in a Western language context, the normal sequence of the Roman alphabet is observed.

When obsolete or unusual romanisations of Chinese words occur in entries in Bibliography C, they are followed, wherever possible, by the romanisations adopted as standard in the present work. If inserted in the title, these are enclosed in square brackets; if they follow it, in round brackets. When Chinese words or phrases occur romanised according to the Wade–Giles system or related systems, they are assimilated to the system here adopted (cf. Vol. 1, p. 26) without indication of any change. Additional notes are added in round brackets. The reference numbers do not necessarily begin with (1), nor are they necessarily consecutive, because only those references required for this volume of the series are given.

Korean and Vietnamese books and papers are included in Bibliographies A and B. As explained in Vol. 1, pp. 21ff., reference numbers in italics imply that the work is in one or other of the East Asian languages.

A. CHINESE AND JAPANESE BOOKS BEFORE + 1800, AND ALL GAZETTEERS

Each entry gives particulars in the following order:
(*a*) title, alphabetically arranged, with characters;
(*b*) alternative title, if any;
(*c*) translation of title;
(*d*) cross-reference to closely related book, if any;
(*e*) dynasty;
(*f*) date as accurate as possible;
(*g*) name of author or editor, with characters;
(*h*) title of other book, if the text of the work now exists only incorporated therein; or, in special cases, references to sinological studies of it;
(*i*) references to translations, if any, given by the name of the translator in Bibliography C;
(*j*) notice of any index or concordance to the book if such a work exists;
(*k*) reference to the number of the book in the *Tao Tsang* catalogue of Wieger (6), if applicable;
(*l*) reference to the number of the book in the *San Tsang* (Tripitaka) catalogues of Nanjio (1) and Takakusu & Watanabe, if applicable.

Words which assist in the translation of titles are added in round brackets.

Alternative titles or explanatory additions to the titles are added in square brackets.

It will be remembered that in Chinese indexes words beginning *Chh-* are all listed together after *Ch-*, and *Hs-* after *H-*, but that this applies to initial words of titles only. Where there are any differences between the entries in these bibliographies and those in earlier Vols., the information here given is to be taken as more correct.

An interim list of references to the editions used in the present work, and to the *tshang-shu* collections in which books are available, has been given in Vol. 4, pt. 3, pp. 913ff., and is available as a separate brochure.

ABBREVIATIONS

C/Han	Former Han.
E/Wei	Eastern Wei.
H/Han	Later Han.
H/Shu	Later Shu (Wu Tai).
H/Thang	Later Thang (Wu Tai).
H/Chin	Later Chin (Wu Tai).
S/Han	Southern Han (Wu Tai).
S/Phing	Southern Phing (Wu Tai).
J/Chin	Jurchen Chin.
L/Sung	Liu Sung.
N/Chou	Northern Chou.
N/Chhi	Northern Chhi.
N/Sung	Northern Sung (before the removal of the capital to Hangchow).
N/Wei	Northern Wei.
S/Chhi	Southern Chhi.
S/Sung	Southern Sung (after the removal of the capital to Hangchow).
W/Wei	Western Wei.

Chan Kuo Tshê 戰國策.
Records of the Warring States.
Chhin or later.
Author unknown.
Textual refs. are to the *Ssu Pu Tshung Khan* edition.

Chiang-Hua Hsien Chih 江華縣志.
Gazetteer of Chiang-Hua County [Hu-Nan].
Chhing, 1870 (re-edition of Yung Chêng edition, 1769).
Ed. Liu Hua-Pang 劉華邦.

Chin Shih 金史.
History of the Chin (Jurchen) Dynasty.
Yüan, *c.* +1345.
Eds. Tho-Tho (Toktaga) & Ouyang Hsüan 脫脫, 歐陽玄.
Textual refs. are to the Chung Hua edition, Peking, 1975.

Chin Shu 晉書.
History of the Chin Dynasty.
Thang, +635.
Ed. Fang Hsüan-Ling 房玄齡.
Textual refs. are to the Chung Hua edition, Peking, 1974.

Chiu Huang Pên Tshao 救荒本草.
Treatise on Wild Food Plants for Use in Emergencies.
Ming, +1406, reprinted 1525, 1555 etc.
Chu Hsiao 朱橚 (prince of the Ming) Chou Ting Wang 周定王.
Included as chs. 46 to 59 of *Nung Chêng Chhüan Shu* (q.v.).

Chou Li 周禮.
Record of the Institutions (lit. the Rites) of the Chou (Dynasty) [descriptions of all government official posts and their duties].
C/Han [perhaps containing some material from late Chou].
Compilers unknown.
Textual refs. are to the I Wên Yin Shu Kuan edition, Taipei, 1976.

Chou Shu 周書.
History of the Chou Dynasty.
Thang, *c.* +583.
Ed. Linghu Tê-Fên 令狐德棻.
Textual refs. are to the Chung Hua edition, Peking, 1971.

Chu Phu 竹譜.
Monograph on Bamboos.
Chin, +4th century, although some scholars consider that it dates from the former (Liu) Sung (+5th century).
Tai Khai-Chih 戴凱之.
Textual refs. are to the Shang Wu edition, Shanghai, 1939.

Chuang Tzu 莊子.
The Book of Master Chuang.
[=Nan Hua Chên Chhing]
Chou, *c.* −290.
Chuang Chou 莊周.
References are to the text printed in *Chuang-Tzu Yin-Tê* 莊子引得 (Harvard-Yenching Institute *Sinological Index Series* no. 20, Peiping, 1947).

Chung Shu Shu 種樹書.
The Manual of Arboriculture.
Ming, +14th century. [Sometimes att. Yüan or even Thang. Chhên Chih and other scholars date it to early Ming.]
Yü Tsung-Pên 俞宗本.
Textual refs. are to the Nung Yeh edition, Peking, 1962.

Chha Ching 茶經.
The Manual of Tea (*Camellia* (*Thea*) *sinensis*).
Thang, *c.* +770
Lu Yü 陸羽.

Chhên Fu Nung Shu 陳旉農書.
Chhên Fu's Book of Agriculture.
Sung, +1149.
Textual refs. are to the Chung Hua edition, Peking, 1956; based on *Tshung Shu Chi Chhêng* series, Shang Wu, Shanghai.

Chhêng-Tê Fu Chih 承德府志.
Gazetteer of Chhêng-Tê Prefecture [Ho-Pei].
Chhing, 1887.
Ed. Hai Chung 海忠.

Chhi Min Yao Shu 齊民要術.
Essential Techniques for the Peasantry.
N/Wei, *c.* +535.
Chia Ssu-Hsieh 賈思勰.
Textual refs. are to the Nung Yeh edition by Shih Shêng-Han 石聲漢, Peking 1961, reprinted 1981.

Chhin Ting Chhing Liang Shan Chih 欽定清凉山志.
Imperially Commissioned Gazetteer of Chhing Liang Shan [Shan-Hsi].
Chhing, +1786.

Chhing Liang Shan Chih 清凉山志.
Gazetteer of Chhing Liang Mountain (Wu Thai Shan) [Shan-Hsi].
Ming, +1596.
Ed. Chên Chhêng 鎮澄.

Chhüan Fang Pei Tsu 全芳備祖.
The Complete Assembly of Perfumes.
Sung, *c.* +1225.
Ed. Chhen Ching-Chê 陳景沂.
Textual refs. are to the Nung Yeh edition by Chhên Jung 陳詠, Peking, 1982.

Chhün Fang Phu 羣芳譜.
The Assembly of Perfumes [Thesaurus of Botany].
Ming, *c.* +1621.
Wang Hsiang-Chin (aka Erh Ju Thing) 王象晉.

Êrh Ya 爾雅.
The Literary Expositor (dictionary).
Chou material, stabilised in Chhin or C/Han.
Compiler unknown.
Enlarged and commented on *c.* +300 by Kuo Phu 郭璞.
Textual refs. are to the Shang Wu edition, Shanghai, 1937 (*Tshung Shu Chi Chhêng*).

Êrh Ya Shu 爾雅疏.
Exegesis to the Erh Ya.
Sung.
Hsing Ping (+932 to + 1010) 邢昺.

Fan Chhuan Wên Chi 樊川文集.
Collected Works of Tu Mu.
Thang.
Tu Mu 杜牧.
Textual refs. are to the *Ssu Pu Tshung Khan* edition.

Fan Shêng-Chih Shu 氾勝之書.
The Book of Fan Shêng-Chih.
C/Han, *c.* −10.
Fan Shêng-Chih 氾勝之.
Text reconstructed by Wan Kuo-Ting 萬國鼎.
Nung Yeh, Peking, 1957; 3rd edition, 1980.

Fang-Shan Hsien Chih 房山縣志.
Gazetteer of Fang-Shan County [Ho-Pei].
Min Kuo, 1928.
Ed. Kao Shu-Kuan 高書官 *et al.*
Textual refs. are to the Taipei edition.

Fêng-Hua Hsien Chih 奉化縣志.
The Gazetteer of Fêng-Hua County, [Chekiang].
Chhing, 1908.
Ed. Li Chhien-Phan 李前泮.

Fu-Ning Fu Chih 福寧府志.
Gazetteer of Fu-Ning Prefecture [Fukien].
(Kuang Hsü reprint).
Chhing, +1762.
Ed. Li Pa 李拔.

Han Shu 漢書.
The History of the Han Dynasty.
C/Han, between +32 and +92.
Pan Ku 班固.
Textual refs. are to the Chung Hua edition, Peking, 1962.

Hua Ching 花鏡.
The Mirror of Flowers.
Chhing, +1688.
Chhên Fu-Yao 陳扶搖.
Textual refs. are to the Peking edition by I Chhin-Hêng 伊欽恒 (1962). Republished, Nung Yeh, Peking, 1979.

Hua Yang Kuo Chih 華陽國志.
Records of the Country South of Mount Hua.
Chin, +347.
Chhang Chhü 常璩.
Textual refs. are to the Shang Wu edition, Shanghai, 1939 (*Tshung Shu Chi Chhêng*).

Huai Nan Tzu 淮南子.
The Book of (the Prince of) Huai Nan [Compendium of natural philosophy].
C/Han, *c.* −120.
Written by a group of scholars gathered by Liu An 劉安, Prince of Huai Nan 淮南.
Textual refs. are to Liu Wên-Tien 劉文典, *Huai-Nan Hung-Lieh Chi-Chieh* 淮南鴻烈集解, first published Shanghai: Shang-Wu, 1923.

Huang Ming Ching Shih Wên Pien 皇明經世文編.
A Compilation of Essays on Classical Subjects written during the Ming [Dynasty].
Ming, +1638.
Chhên Tzu-Lung, Hsü Fu-Yüan, Sung Chêng-

Huang Ming Ching Shih Wên Pien (cont.)
Pi 陳子龍, 徐孚遠, 宋徵璧.
Ch. 157 Liu Chuang-Hsiang Kung Tsou Shu 劉莊襄公奏疏: Chih Ho Liu Liu 治河六柳.
Textual refs. are to the Ming, Chhung Chên edition (Phing Lu Thang). Reprinted, Taipei, Kuo Fêng Thu Shu, 1964.
Hsi Yang Tsa Tsu 西陽雜俎.
An Offertory from The West.
Thang, +860.
Tuan Chhêng-Shih 段成式.
Hsin Thang Shu 新唐書.
New History of the Thang Dynasty.
Sung, +1061.
Ouyang Hsiu 歐陽修 & Sung Chhi 宋祁.
Textual refs. are to the Chung Hua edition, Peking, 1975.
Hsing Shui Chin Chien 行水金鑑.
Golden Mirror of the Flowing Waters.
Chhing, +1725.
Fu Tsê-Hung 傅澤洪.
Hsüan-Phing Hsien Chih 宣平縣志.
Gazetteer of Hsüan-Phing County [Chekiang].
Chhing, 1878.
Eds. Phi Shu-Thang 皮樹棠 & Phi Hsi-Jui 皮錫瑞.
Hsün Tzu 荀子.
The Book of Master Hsün.
Late Warring States, *c.* −340 to −245.
Textual refs. are to the Shang Wu edition, Shanghai, 1930 (*Tshung Shu Chi Chhêng*).

I Chien Chih 夷堅志.
Account of Things Outlandish and Wise.
Sung, *c.* +1170.
Hung Mai 洪邁.
Textual refs. are to the Chung Hua edition, Peking, 1981 (4 vols).

Khai Ho Chi 開河記.
Sui, +581 to +618.
Han Wo 韓偓.
Now exists as ch. 92 of *Hsing Shui Chin Chien* 行水金鑑 by Fu Tsê-Hung 傅澤洪.
Textual refs. are to the *Kuo Hsüeh Chi Pên Tshung Shu* edition, Shanghai, 1936.
Khai-Hua Hsien Chih 開華縣志.
The Gazetteer of Khai-Hua County [Chekiang].
Ming, +1636.
Ku Chin Chu 古今註.
Commentary on the Past and Present.
Western Chin, +3rd century.
Tshui Pao 崔豹.
Ku Chin Thu Shu Chi Chhêng 古今圖書集成.
Imperial Encyclopaedia [or: Imperially Commissioned Compendium of Literature and Illustrations, Ancient and Modern].
Chhing, +1726.
Ed. Chhên Mêng-Lei 陳夢雷.
Kuan Tzu 管子.
The Book of Master Kuan.
Chou & C/Han. Perhaps mainly compiled in the Chi-Hsia Academy (late −4th century) in part from older materials.
Attrib. Kuan Chung 管仲.
Transl. used: Than, Wên, Hsiao & Maverick (1). Also Rickett (1).
Textual refs. are to the *Ssu Pu Tshung Khan* edition.
Kuang Chih I 廣志繹.
Deciphering the Extensive Records.
Ming.
Used Khang Hsi edition, +1676.
Wang Shih-Hsing 王士性.
Kuang Chhün Fang Phu 廣羣芳譜.
The 'Assembly of Perfumes' Enlarged [Thesaurus of Botany.]
Chhing, +1708.
Ed. Wang Hao 汪灝.

Li Chi 禮記.
Record of Rites.
Ascr. C/Han, *c.* −70 to −50, but really H/Han, between +80 and +105, though the earliest pieces included may date from the time of the *Analects* (*c.* −465 to −450).
Attr. ed. Tai Shêng 戴聖.
Actual ed. Tshao Pao 曹褒.
Textual refs. are to the I Wên Yin Shu Kuan edition, Taipei, 1976.
Li Chih Phu 荔枝譜.
Monograph on the Litchi.
Sung, +1059.
Chhai Hsiang 蔡襄.
Lin Hai Shui Thu I Wu Chih Chi Chiao 臨海水土異物志輯校.
Annotated Account of Extraordinary Things of the Lands and Waters along the Ocean.
Three Dynasties/Wu.
Wu Shên-Ying 吳沈瑩.
Textual refs. are to the edition by Chang Chhung-Kên 張崇根, Nung Yeh, Peking, 1981.
Lin Hsien Chih 林縣志.
Gazetteer of Lin County [Ho-Nan].
Chhing, +1752.
Eds. Chang Fêng-Thai 張鳳臺 & Li Chien-Chhüan 李見荃.
Lin Hsien Chih 林縣志
Gazetteer of Lin County [Ho-Nan].
Min Kuo, 1932.
Ling Yin Ssu Chih 靈隱寺志
The Gazetteer of the Ling Yin Monastery [Chekiang].
Chhing, +1672.
Liu Ho-Tung Chi 柳河東集.
Collected Works of Liu Tsung-Yüan.
Thang, early +9th century.
Liu Tsung-Yüan 柳宗元.
Textual refs. are to the Shang Wu edition, Shanghai, 1975.
Lun Yu 論語.
Conversations and Discourses (of Confucius)

Lun Yü (cont.)
[perhaps Discussed Sayings, Normative Sayings, or Selected Sayings]; Analects.
Chou (Lu), *c.* −465 to −450.
Compiled by disciples of Confucius (chs. 16, 17, 18, and 20 are later interpolations).
Textual refs. are to Legge (2).

Mêng Chhi Pi Than 夢溪筆談.
Dream Pool Essays.
N/Sung, *c.* +1086; last Supplement dated +1091.
Shên Kua (+1030 to +1095) 沈括.
Textual refs. are to the Chung Hua edition, Peking, 1957.

Mêng Tzu 孟子.
The Book of Master Mêng (Mencius).
Chou, *c.* −290.
Mêng Kho 孟軻.

Ming Shih 明史.
History of the Ming Dynasty.
Chhing, begun +1646, completed +1736.
Chang Thing-Yü 張廷玉 *et al.*
Textual refs. are to the Chung Hua edition, Peking, 1974.

Môshī Himbutsu Zukō 毛詩品物圖考.
Illustrated Study of the Creatures (Plants and Animals) in the *Book of Odes*.
Japan, +1785 (Kyoto).
Subsequently reprinted in China without Katakana readings.
Oka Kōyoku 岡公翼.

Nan Fang Tshao Mu Chuang 南方草木狀.
A Prospect of the Plants and Trees of the Southern Regions.
Chin, +304.
Hsi Han 嵇含.
Textual refs. are to Li Hui-Lin (11).

Nan-Phing Hsien Chih 南平縣志.
Gazetteer of Nan-Phing County [Fukien].
Min Kuo, 1919.
Ed. Tshai Chien-Hsien 蔡建賢.
Textual refs. are to the Taipei edition.

Nung Chêng Chhüan Shu 農政全書.
Complete Treatise on Agricultural Administration.
Ming, composed +1625–28, printed +1639.
Hsü Kuang-Chhi 徐光啓.
Ed. Chhên Tzu-Lung 陳子龍.
Textual refs. are to the 1843 reproduction of Palace edition.

Nung Sang Chi Yao 農桑輯要.
Fundamentals of Agriculture and Sericulture.
Yüan, +1273.
Preface by Wang Phan 王磐. Imperially commissioned and produced by the Agricultural Extension Bureau 司農司.
Probable editor, Mêng Chhi 孟祺. Probable later editors, Chhang Shih-Wên (*c.* +1286) 暢師文, Miao Hao-Chhien (*c.* +1318) 苗好謙.
Textual refs. are to the Nung Yeh edition, Peking, 1982.
Annotated by Shih Shêng-Han 石聲漢 using Palace edition.

Nung Shu 農書.
Agricultural Treatise.
Yüan, +1313.
Wang Chên 王禎.
Textual refs. are to the Ming Palace Edition.

Ouyang Wên Chung Kung Wên Chi 歐陽文忠公文集.
The Works of the Loyal Literatus Ouyang.
Sung, *c.* +1007.
Ouyang Hsiu 歐陽修.
Textual refs. are to the *Ssu Pu Tshung Khan* 1922 edition.

Pên Tshao Kang Mu 本草綱目.
The Great Pharmacopoeia [or, The Pandects of Pharmaceutical Natural History].
Ming, +1596.
Li Shih-Chên 李時珍.
Textual refs. are to the Jên Min Wei Shêng edition, Peking, 1979.

Pên Tshao Thu Ching 本草圖經.
Illustrated Pharmacopoeia; or, Illustrated Treatise of Pharmaceutical Natural History.
Sung, +1061.
Su Sung 蘇頌 *et al.*
Now preserved only in numerous quotations in the later pandects of pharmaceutical natural history.

Pien Min Thu Tsuan 便民圖纂.
Everyman's Handy Illustrated Compendium [or, The Farmstead Manual].
Ming, +1502; repr. +1552, +1593.
Author unknown but could be Khuang Fan 鄺璠.
Textual refs. are to the edition by Shih Shêng-Han & Khang Chhêng-I 石聲漢, 康成懿, Peking, 1959.

San Kuo Chih 三國志.
History of the Three Kingdoms [+220 to +280].
Chin, *c.* +290.
Chhên Shou 陳壽.
Textual refs. are to the Chung Hua edition, Peking, 1959.

Shan Hai Ching 山海經.
Classic of the Mountains and Rivers.
Chou & C/Han.
Writers unknown.
Textual refs. are to the Shanghai Ku Chi edition, edited by Yüan Kho 袁珂, 1980.

Shan-Hsi Thung Chih 山西通志.
Gazetteer of Shan-Hsi Province.
Chhing, +1733.
Ed. Lo Shih-Lin 羅石麟 *et al.*

Shan-Hua Hsien Chih. 善化縣志.
Gazetteer of Shan-Hua County [Hu-Nan].

Shan-Hua Hsien Chih (cont.)
Chhing, 1878.
Textual refs. are to the Taipei edition.
Shang Chün Shu 商君書.
Book of the Lord Shang.
Chou, −4th or −3rd century.
Attrib. Kungsun Yang 公孫鞅.
Textual refs. are to the Shang Wu edition, Shanghai, 1939.
Shên Nung Pên Tshao Ching 神農本草經.
Classical Pharmacopoeia of the Heavenly Husbandman.
C/Han, based on Chou & Chhin material but not reaching final form before the +2nd century.
Writers unknown.
Lost as a separate work, but the basis of all subsequent compendia of pharmaceutical natural history, in which it is constantly quoted.
Shih Chi 史記.
Historical Record (down to −99).
C/Han, *c.* −90.
Ssuma Chhien 司馬遷 and his father Ssuma Than 司馬談.
Textual refs. are to the Chung Hua edition, Peking, 1959.
Shih Ching 詩經.
Book of Odes (ancient folksongs).
Chou, −11th to −7th centuries (Dobson's dating).
Writers and compilers unknown.
Shou Shih Thung Khao 授時通考.
Compendium of Works and Days.
Chhing, +1742.
Compiled by Imperial order under the direction of O-Erh-Thai 鄂爾泰.
Textual refs. are to the Chung Hua edition, Peking, 1956.
Shu Ching 書經.
Historical Classic [or, Book of Documents].
The 29 'Chin Wên' documents mainly Chou (a few pieces possibly Shang); the 21 'Ku Wên' chapters a 'forgery' by Mei Tsê 梅賾, *c.* +320, using fragments of genuine antiquity. Of the former, 13 are considered to go back to the −10th Century, 10 to the −8th and 6 not before the −5th. Some scholars accept only 16 or 17 as pre-Confucian. Writers unknown.
Translation by Legge (1).
Shu Hsü Pu 樹畜部.
The Division of Trees and Livestock.
Ming, +1504.
Sung Hsü 宋詡.
Textual refs. are to the *Ssu Khu Chhüan Shu* edition.
In Sung Hsü: *Chu Yü Shan Fang Tsa Pu* 竹嶼山房雜部 (32 ch).
Shui Ching Chu 水經註.
Commentary on the *Waterways Classic* [geographical account greatly extended].
N/Wei, late +5th/early +6th century.
Li Tao-Yüan 酈道元.
Shuo Wên.
See *Shuo Wên Chieh Tzu.*
Shuo Wên Chieh Tzu 說文解字.
Analytical Dictionary of Characters (lit. Explanations of Simple Characters and Analyses of Composite Ones).
H/Han, +121.
Hsu Shên 許愼.
Ssu Min Yüeh Ling 四民月令.
Monthly Ordinances for the Four Sorts of People.
H/Han, *c.* +160.
Tshui Shih 崔寔.
Textual refs. are to the edition by Miao Chhi-Yü, Nung Yeh, Peking, 1981.
Ssu Ming Tho Shan Shui Li Pei Lan 四明它山水利備覽.
Irrigation Canals of the Mt Tho District [nr Ning-Po].
S/Sung, +1242.
Wei Hsien 魏峴.
Textual refs. are to the Chhung Chên 14 edition, 1642.
Ssu Shih Tsuan Yao 四時纂要.
Important Rules for the Four Seasons.
Thang, *c.* +750.
Compiled by Han O 韓鄂.
Textual refs. are to the edition edited & annotated by Miao Chhi-Yü 繆啓愉, Nung Yeh, Peking, 1981.
Su Tung-Pho Chhüan Chi 蘇東坡全集.
The Collected Works of Su Tung-Pho.
Sung.
Su Shih (Su Tung-Pho) 蘇軾.
Various editions.
Sung Shu 宋書.
The History of the (Liu) Sung Dynasty.
S/Chhi, *c.* +500.
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Note: page numbers in italics refer to figures and tables. Page numbers suffixed (n) refer to footnotes. In the arrangement of Chinese words, Chh- and Hs- follow normal alphabetical sequence, and *ü* is treated as equivalent to *u*.

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TABLE OF CHINESE DYNASTIES

夏	HSIA kingdom (legendary?)		*c.* −2000 to *c.* −1520
商	SHANG (YIN) kingdom		*c.* −1520 to *c.* −1030
周	CHOU dynasty (Feudal Age)	Early Chou period	*c.* −1030 to −722
		Chhun Chiu period 春秋	−722 to −480
		Warring States (Chan Kuo) period 戰國	−480 to −221
First Unification	秦	CHHIN dynasty	−221 to −207
	漢 HAN dynasty	Chhien Han (Earlier or Western)	−202 to +9
		Hsin interregnum	+9 to +23
		Hou Han (Later or Eastern)	+25 to +220
	三國	SAN KUO (Three Kingdoms period)	+211 to +265
First Partition	蜀	SHU (HAN)	+211 to +264
	魏	WEI	+200 to +265
	吳	WU	+222 to +280
Second Unification	晉	CHIN dynasty: Western	+265 to +317
		Eastern	+317 to +420
	劉宋	(Liu) SUNG dynasty	+420 to +479
Second Partition		Northern and Southern Dynasties (Nan Pei chhao)	
	齊	CHHI dynasty	+479 to +502
	梁	LIANG dynasty	+502 to +557
	陳	CHHÊN dynasty	+557 to +589
	魏	Northern (Thopa) WEI dynasty	+386 to +535
		Western (Thopa) WEI dynasty	+535 to +556
		Eastern (Thopa) WEI dynasty	+534 to +550
	北齊	Northern CHHI dynasty	+550 to +577
	北周	Northern CHOU (Hsienpi) dynasty	+557 to +581
Third Unification	隋	SUI dynasty	+581 to +618
	唐	THANG dynasty	+618 to +906
Third Partition	五代	WU TAI (Five Dynasty period) (Later Liang, Later Thang (Turkic), Later Chin (Turkic), Later Han (Turkic) and Later Chou)	+907 to +960
	遼	LIAO (Chhitan Tartar) dynasty	+907 to +1124
		West LIAO dynasty (Qarā-Khiṭāi)	+1124 to +1211
	西夏	Hsi Hsia (Tangut Tibetan) state	+986 to +1227
Fourth Unification	宋	Northern SUNG dynasty	+960 to +1226
	冂	Southern SUNG dynasty	+1127 to +1279
	金	CHIN (Jurchen Tartar) dynasty	+1115 to +1234
	元	YÜAN (Mongol) dynasty	+1260 to +1368
	明	MING dynasty	+1368 to +1644
	清	CHHING (Manchu) dynasty	+1644 to +1911
	民國	Republic	+1912

N.B. When no modifying term in brackets in given, the dynasty was purely Chinese. Where the overlapping of dynasties and independent states becomes particularly confused, the tables of Wieger (1) will be found useful. For such periods, especially the Second and Third Partitions, the best guide is Eberhard (9). During the Eastern Chin period there were no less than eighteen independent States (Hunnish, Tibetan, Hsienpi, Turkic, etc.) in the north. The term 'Liu chhao' (Six Dynasties) is often used by historians of literature. It refers to the south and covers the period from the beginning of the +3rd to the end of the +6th centuries, including (San Kuo) Wu, Chin, (Liu) Sung, Chhi, Liang and Chhen. For all details of reigns and rulers see Moule & Yetts (1).

ROMANISATION CONVERSION TABLES

BY ROBIN BRILLIANT

PINYIN/MODIFIED WADE-GILES

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
a	a	chou	chhou
ai	ai	chu	chhu
an	an	chuai	chhuai
ang	ang	chuan	chhuan
ao	ao	chuang	chhuang
ba	pa	chui	chhui
bai	pai	chun	chhun
ban	pan	chuo	chho
bang	pang	ci	tzhu
bao	pao	cong	tshung
bei	pei	cou	tshou
ben	pên	cu	tshu
beng	pêng	cuan	tshuan
bi	pi	cui	tshui
bian	pien	cun	tshun
biao	piao	cuo	tsho
bie	pieh	da	ta
bin	pin	dai	tai
bing	ping	dan	tan
bo	po	dang	tang
bu	pu	dao	tao
ca	tsha	de	tê
cai	tshai	dei	tei
can	tshan	den	tên
cang	tshang	deng	têng
cao	tsho	di	ti
ce	tshê	dian	tien
cen	tshên	diao	tiao
ceng	tshêng	die	dieh
cha	chha	ding	ting
chai	chhai	diu	tiu
chan	chhan	dong	tung
chang	chhang	dou	tou
chao	chhao	du	tu
che	chhê	duan	tuan
chen	chhên	dui	tui
cheng	chhêng	dun	tun
chi	chhih	duo	to
chong	chhung	e	ê, o

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
en	ên	jia	chia
eng	êng	jian	chien
er	êrh	jiang	chiang
fa	fa	jiao	chiao
fan	fan	jie	chieh
fang	fang	jin	chin
fei	fei	jing	ching
fen	fên	jiong	chiung
feng	fêng	jiu	chiu
fo	fo	ju	chü
fou	fou	juan	chüan
fu	fu	jue	chüeh, chio
ga	ka	jun	chün
gai	kai	ka	kha
gan	kan	kai	khai
gang	kang	kan	khan
gao	kao	kang	khang
ge	ko	kao	khao
gei	kei	ke	kho
gen	kên	kei	khei
geng	kêng	ken	khên
gong	kung	keng	khêng
gou	kou	kong	khung
gu	ku	kou	khou
gua	kua	ku	khu
guai	kuai	kua	khua
guan	kuan	kuai	khuai
guang	kuang	kuan	khuan
gui	kuei	kuang	khuang
gun	kun	kui	khuei
ha	ha	kun	khun
hai	hai	kuo	khuo
han	han	la	la
hang	hang	lai	lai
hao	hao	lan	lan
he	ho	lang	lang
hei	hei	lao	lao
hen	hên	le	lê
heng	hêng	lei	lei
hong	hung	leng	lêng
hou	hou	li	li
hu	hu	lia	lia
hua	hua	lian	lien
huai	huai	liang	liang
huan	huan	liao	liao
huang	huang	lie	lieh
hui	hui	lin	lin
hun	hun	ling	ling
huo	huo	liu	liu
ji	chi	lo	lo

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
long	lung	ou	ou
lou	lou	pa	pha
lu	lu	pai	phai
lü	lü	pan	phan
luan	luan	pang	phang
lüe	lüeh	pao	phao
lun	lun	pei	phei
luo	lo	pen	phên
ma	ma	peng	phêng
mai	mai	pi	phi
man	man	pian	phien
mang	mang	piao	phiao
mao	mao	pie	phieh
mei	mei	pin	phin
men	mên	ping	phing
meng	mêng	po	pho
mi	mi	pou	phou
mian	mien	pu	phu
miao	miao	qi	chhi
mie	mieh	qia	chhia
min	min	qian	chhien
ming	ming	qiang	chhiang
miu	miu	qiao	chhiao
mo	mo	qie	chhieh
mou	mou	qin	chhin
mu	mu	qing	chhing
na	na	qiong	chhiung
nai	nai	qiu	chhiu
nan	nan	qu	chhü
nang	nang	quan	chhüan
nao	nao	que	chhüeh, chhio
nei	nei	qun	chhün
nen	nên	ran	jan
neng	nêng	rang	jang
ng	ng	rao	jao
ni	ni	re	jê
nian	nien	ren	jên
niang	niang	reng	jêng
niao	niao	ri	jih
nie	nieh	rong	jung
nin	nin	rou	jou
ning	ning	ru	ju
niu	niu	rua	jua
nong	nung	ruan	juan
nou	nou	rui	jui
nu	nu	run	jun
nü	nü	ruo	jo
nuan	nuan	sa	sa
nüe	nio	sai	sai
nuo	no	san	san
o	o, ê	sang	sang

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
sao	sao	wai	wai
se	sê	wan	wan
sen	sên	wang	wang
seng	sêng	wei	wei
sha	sha	wen	wên
shai	shai	weng	wêng
shan	shan	wo	wo
shang	shang	wu	wu
shao	shao	xi	hsi
she	shê	xia	hsia
shei	shei	xian	hsien
shen	shen	xiang	hsiang
sheng	shêng, sêng	xiao	hsiao
shi	shih	xie	hsieh
shou	shou	xin	hsin
shu	shu	xing	hsing
shua	shua	xiong	hsiung
shuai	shuai	xiu	hsiu
shuan	shuan	xu	hsü
shuang	shuang	xuan	hsüan
shui	shui	xue	hsüeh, hsio
shun	shun	xun	hsün
shuo	shuo	ya	ya
si	ssu	yan	yen
song	sung	yang	yang
sou	sou	yao	yao
su	su	ye	yeh
suan	suan	yi	i
sui	sui	yin	yin
sun	sun	ying	ying
suo	so	yo	yo
ta	tha	yong	yung
tai	thai	you	yu
tan	than	yu	yü
tang	thang	yuan	yüan
tao	thao	yue	yüeh, yo
te	thê	yun	yün
teng	thêng	za	tsa
ti	thi	zai	tsai
tian	thien	zan	tsan
tiao	thiao	zang	tsang
tie	thieh	zao	tsao
ting	thing	ze	tsê
tong	thung	zei	tsei
tou	thou	zen	tsên
tu	thu	zeng	tsêng
tuan	thuan	zha	cha
tui	thui	zhai	chai
tun	thun	zhan	chan
tuo	tho	zhang	chang
wa	wa	zhao	chao

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
zhe	chê	zhui	chui
zhei	chei	zhun	chun
zhen	chên	zhuo	cho
zheng	chêng	zi	tzu
zhi	chih	zong	tsung
zhong	chung	zou	tsou
zhou	chou	zu	tsu
zhu	chu	zuan	tsuan
zhua	chua	zui	tsui
zhuai	chuai	zun	tsun
zhuan	chuan	zuo	tso
zhuang	chuang		

MODIFIED WADE-GILES/PINYIN

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
a	a	chhio	que
ai	ai	chhiu	qiu
an	an	chhiung	qiong
ang	ang	chho	chuo
ao	ao	chhou	chou
cha	zha	chhu	chu
chai	zhai	chhuai	chuai
chan	zhan	chhuan	chuan
chang	zhang	chhuang	chuang
chao	zhao	chhui	chui
chê	zhe	chhun	chun
chei	zhei	chhung	chong
chên	zhen	chhü	qu
chêng	zheng	chhüan	quan
chha	cha	chhüeh	que
chhai	chai	chhün	qun
chhan	chan	chi	ji
chhang	chang	chia	jia
chhao	chao	chiang	jiang
chhê	che	chiao	jiao
chhên	chen	chieh	jie
chhêng	cheng	chien	jian
chhi	qi	chih	zhi
chhia	qia	chin	jin
chhiang	qiang	ching	jing
chhiao	qiao	chio	jue
chhieh	qie	chiu	jiu
chhien	qian	chiung	jiong
chhih	chi	cho	zhuo
chhin	qin	chou	zhou
chhing	qing	chu	zhu

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
chua	zhua	huan	huan
chuai	zhuai	huang	huang
chuan	zhuan	hui	hui
chuang	zhuang	hun	hun
chui	zhui	hung	hong
chun	zhun	huo	huo
chung	zhong	i	yi
chü	ju	jan	ran
chüan	juan	jang	rang
chüeh	jue	jao	rao
chün	jun	jê	re
ê	e, o	jên	ren
ên	en	jêng	reng
êng	eng	jih	ri
êrh	er	jo	ruo
fa	fa	jou	rou
fan	fan	ju	ru
fang	fang	jua	rua
fei	fei	juan	ruan
fên	fen	jui	rui
fêng	feng	jun	run
fo	fo	jung	rong
fou	fou	ka	ga
fu	fu	kai	gai
ha	ha	kan	gan
hai	hai	kang	gang
han	han	kao	gao
hang	hang	kei	gei
hao	hao	kên	gen
hên	hen	kêng	geng
hêng	heng	kha	ka
ho	he	khai	kai
hou	hou	khan	kan
hsi	xi	khang	kang
hsia	xia	khao	kao
hsiang	xiang	khei	kei
hsiao	xiao	khên	ken
hsieh	xie	khêng	keng
hsien	xian	kho	ke
hsin	xin	khou	kou
hsing	xing	khu	ku
hsio	xue	khua	kua
hsiu	xiu	khuai	kuai
hsiung	xiong	khuan	kuan
hsü	xu	khuang	kuang
hsüan	xuan	khuei	kui
hsüeh	xue	khun	kun
hsün	xun	khung	kong
hu	hu	khuo	kuo
hua	hua	ko	ge
huai	huai	kou	gou

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
ku	gu	mu	mu
kua	gua	na	na
kuai	guai	nai	nai
kuan	guan	nan	nan
kuang	guang	nang	nang
kuei	gui	nao	nao
kun	gun	nei	nei
kung	gong	nên	nen
kuo	guo	nêng	neng
la	la	ni	ni
lai	lai	niang	niang
lan	lan	niao	niao
lang	lang	nieh	nie
lao	lao	nien	nian
lê	le	nin	nin
lei	lei	ning	ning
lêng	leng	niu	nüe
li	li	niu	niu
lia	lia	no	nuo
liang	liang	nou	nou
liao	liao	nu	nu
lieh	lie	nuan	nuan
lien	lian	nung	nong
lin	lin	nü	nü
ling	ling	o	e, o
liu	liu	ong	weng
lo	luo, lo	ou	ou
lou	lou	pa	ba
lu	lu	pai	bai
luan	luan	pan	ban
lun	lun	pang	bang
lung	long	pao	bao
lü	lü	pei	bei
lüeh	lüe	pên	ben
ma	ma	pêng	beng
mai	mai	pha	pa
man	man	phai	pai
mang	mang	phan	pan
mao	mao	phang	pang
mei	mei	phao	pao
mên	men	phei	pei
mêng	meng	phên	pen
mi	mi	phêng	peng
miao	miao	phi	pi
mieh	mie	phiao	piao
mien	mian	phieh	pie
min	min	phien	pian
ming	ming	phin	pin
miu	miu	phing	ping
mo	mo	pho	po
mou	mou	phou	pou

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
phu	pu	tên	den
pi	bi	têng	deng
piao	biao	tha	ta
pieh	bie	thai	tai
pien	bian	than	tan
pin	bin	thang	tang
ping	bing	thao	tao
po	bo	thê	te
pu	bu	thêng	teng
sa	sa	thi	ti
sai	sai	thiao	tiao
san	san	thieh	tie
sang	sang	thien	tian
sao	sao	thing	ting
sê	se	tho	tuo
sên	sen	thou	tou
sêng	seng, sheng	thu	tu
sha	sha	thuan	tuan
shai	shai	thui	tui
shan	shan	thun	tun
shang	shang	thung	tong
shao	shao	ti	di
shê	she	tiao	diao
shei	shei	tieh	die
shên	shen	tien	dian
shêng	sheng	ting	ding
shih	shi	tiu	diu
shou	shou	to	duo
shu	shu	tou	dou
shua	shua	tsa	za
shuai	shuai	tsai	zai
shuan	shuan	tsan	zan
shuang	shuang	tsang	zang
shui	shui	tsao	zao
shun	shun	tsê	ze
shuo	shuo	tsei	zei
so	suo	tsên	zen
sou	sou	tsêng	zeng
ssu	si	tsha	ca
su	su	tshai	cai
suan	suan	tshan	can
sui	sui	tshang	cang
sun	sun	tshao	cao
sung	song	tshê	ce
ta	da	tshên	cen
tai	dai	tshêng	ceng
tan	dan	tsho	cuo
tang	dang	tshou	cou
tao	dao	tshu	cu
tê	de	tshuan	cuan
tei	dei	tshui	cui

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
tshun	cun	wang	wang
tshung	cong	wei	wei
tso	zuo	wên	wen
tsou	zou	wo	wo
tsu	zu	wu	wu
tsuan	zuan	ya	ya
tsui	zui	yang	yang
tsun	zun	yao	yao
tsung	zong	yeh	ye
tu	du	yen	yan
tuan	duan	yin	yin
tui	dui	ying	ying
tun	dun	yo	yue, yo
tung	dong	yu	you
tzhu	ci	yung	yong
tzu	zi	yü	yu
wa	wa	yüan	yuan
wai	wai	yüeh	yue
wan	wan	yün	yun